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Factors Affecting the Quality of Kinerecording

By P. J. HERBST, R. O. DREW and J. M. BRUMBAUGH

Limitations imposed by television and photographic processes, employment of electrical compensation for degradations in detail and contrast rendition, with experimental investigation of various aspects of the system, are reviewed. Conclusions regarding improved recording devices and techniques are offered.

Kinescope recording was initially intended to provide program material to television stations not connected to the major origination centers by either coaxial cable or radio relay facilities. This served to expand the service, to distribute the program expense and to provide advertisers with a larger audience. The rapid growth of interconnection facilities introduces a new problem due to the time difference between the point of program origination and the remote station carrying the same show. The situation can be appreciated by examining Fig. 1 which indicates the problem arising from the time zone difference across the continent. A program originating in New York at 9:00 P.M. would reach the West Coast at 6:00 P.M., much too early for presentation. It appears that the best solution is to record the program on the West Coast at the time of origination and to present a delayed broadcast from this material at 9:00 P.M. Pacific Time. Likewise, a program originating in Los Angeles at 9:00 P.M. would reach the East Coast at midnight, much too late for presentation. One proposed solution is to stage the show at 6:00 P.M. Pacific Time and to transmit it to the East Coast for presentation at 9:00 P.M. Eastern Time, at the same time recording the material for later presentation over the local West Coast Station.

The concentration of experienced talent on the West Coast increases the need for good recordings as does the continuing necessity of providing programs for stations not yet connected by common carrier facilities or unable to transmit the program at the time of origination due to other commitments. While the appeal of television has been sufficient for the public to tolerate a considerable amount of degradation in picture quality, it is obvious that the system must eventually provide enter-

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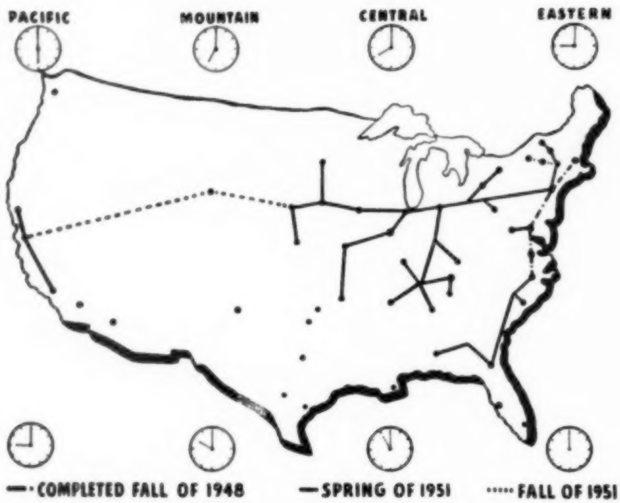


Fig. 1. Basic common carrier facilities for TV.

tainment of a technical quality consistent with that of current studio originations. In view of the importance of this operation to the entire industry, RCA embarked on a broad program of investigation aimed toward uncovering the sources of picture degradation throughout the system and developing the methods whereby the losses and distortions might be minimized. The number of individuals contributing to this effort is too large for separate recognition here as will be appreciated from the fact that personnel at NBC, New York; RCA Engineering Products Dept., Camden; RCA Tube Dept. at both Harrison and Lancaster; the RCA organization in Hollywood; and the RCA Laboratories in Princeton were involved. This paper is intended as a progress report to the industry on the investigations made to date.

Sources of Degradation

While excellent recordings are possible under present conditions, and are being obtained with increasing frequency, such results are not obtained with consistency and the quality of the poorer recordings is so far inferior to studio origination as to cause severe criticism. This picture quality suffers in the loss of detail, the distortion of the gray-scale rendition and in the increase of noise or graininess. In order to obtain the optimum in recordings, the limitations of the system must be understood and the details of operation must be tailored to fit these limitations until the various elements of the system can be improved. The sources of picture degradation are illustrated in Fig. 2.

The first factor affecting quality is the scene lighting. Very contrasty lighting or excessive brightness range is almost certain to introduce spurious shadowing or compression of the gray scale in areas of interest. While the results may not be too bad in the original broadcast, the further distortion introduced by the recording and reproducing processes frequently serve to exaggerate the original defects to a point where the net result is hardly tolerable.

The second factor is the operation of the studio camera. The range in which

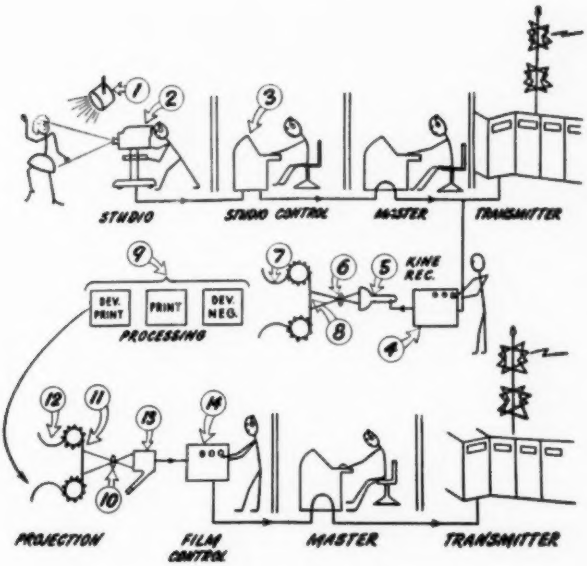


Figure 2.

1. Scene lighting
2. Camera operation
3. Camera control and level setting
4. Recording amplifying circuitry
5. Recording kinescope
6. Recording optical system
7. Camera transport mechanism
8. Film size and emulsion
9. Photographic processing
10. Reproducing optical system
11. Finished recording
12. Projector transport mechanism
13. TV camera pickup tube
14. TV film camera and operation

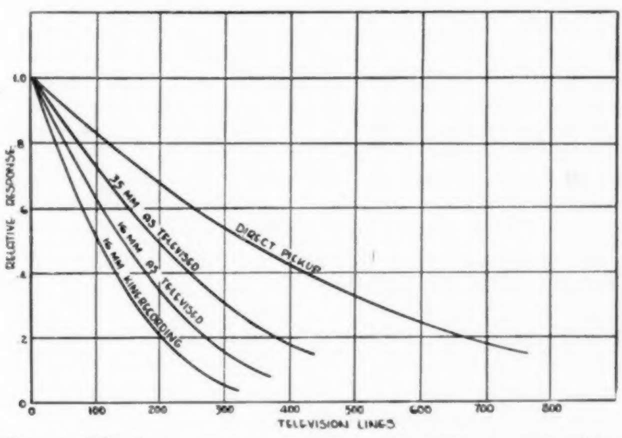


Fig. 3. Effective aperture response, no aperture correction.

an image orthicon will operate without the introduction of excessive distortions due to redistribution effects at the target is not much greater than 30:1; therefore, careful control of the iris of the camera, care in adjusting the operating potentials to insure a reasonable range of operation and precise setting of black levels between cameras are necessary to obtain a picture of optimum quality. Unless the program director, the technical director and the operating personnel all cooperate in this respect, there is nothing that the operator of the recording equipment can do to rectify their mistakes.

The next link in the chain is the amplifying circuitry associated with the recording monitor. In general, this poses no problem since the bandwidth and signal handling range can be made adequate. In fact, it is possible to include some corrective circuits at this point. The adjustment and maintenance of precise levels are more pressing problems than any consideration of losses in the electrical circuits.

The kinescope employed in the monitor represents one of the limiting elements of the system. Considerable effort has been devoted to the improvement of this unit as will be described later. Loss in detail and compression of the contrast range can be introduced at this point.

The optical system of the camera, in fact any lens in the system, can introduce losses in resolution due to poor focus or lens flare. At the present time, these effects are not limiting but improvement in other elements of the system may increase the importance of the losses at such points.

The film transport mechanism in the recording camera can introduce losses by either improper motion of the film or by vibration which causes loss of interlace and smearing of detail.

The film size and the particular emulsion affect both detail and the gray-scale rendition. The film processing also introduces loss of detail and distortion of the contrast depending upon the exposures employed, the development of both negative and print and the precision of the printer.

The television film camera introduces optical and mechanical losses but the most important element in this unit is the pickup tube and its operation. Spot size and dynamic range affect both detail and gray-scale rendition. The latter varies with the particular tube employed and requires either that special compensation be employed or that the characteristics of the recording be adapted to the characteristics of the pickup tube. This is one place where a uniform characteristic is needed, in order that both normal film and kinescope recordings be reproduced with a minimum of distortion. A review of the subject was presented by R. M. Fraser in 1948.[15]

The extent to which fine detail is degraded even under the best current practices may be appreciated by an inspection of Fig. 3. This is a plot of the effective aperture response of a good studio pickup and the reproduction of various types of film material. The subject has been treated in detail by O. H. Schade in previous publications.[1,2,4,6] It is, therefore, sufficient to explain that the plot is in terms of the relative signal amplitude versus television line number.

Several methods of electrically compensating for such losses have been described and circuits are currently in use in many recording studios.[5] Essentially, these circuits are equalizers which accentuate the higher video frequencies representative of the fine picture detail. The precise shape of the response curve and the necessity of including phase compensation to minimize the edge effects due to transients have been discussed in various publications. The effect of such an equalizer

or "aperture compensating" circuit is shown in Figs. 4 and 5. Both are still recordings of the same television signal. Figure 4 shows the results obtained without compensation while Fig. 5 shows the effect when electrical correction is employed. In this case the compensation was excessive as indicated by the pronounced edge effects. However, this was purposely introduced to reduce the need for further correction in the film reproducing equipment. This picture, reproduced over a normal and well-adjusted television film pickup chain, gave very excellent results as regards detail, as shown in Fig. 6. The degree of improvement can be estimated by comparing this result with the reproduction of the uncompensated recording shown in Fig. 7. The extent to which such compensation can be employed is limited by the increase in noise, the accentuation of defects in the original pickup and the introduction of unpleasant edge effects. It is likely to vary with different originations and, at the present time, requires the operator to exercise good judgment in adjusting the compensator for any one scene or program.

The compression of the gray-scale range as the signal progresses through the system is shown in Fig. 8. This subject has also been exhaustively treated by Schade and others.[2,3,4,6,7,8] It will be noted that the linear range of the original studio pickup, when properly adjusted, is in the order of 30 to 1. The same range for normally processed motion picture film when televised without compensation is in the order of 10:1. When the original television studio pickup is photographically recorded and the kinescope recording reproduced over the television system, the linear range is only about 4 to 1. It is, therefore, essential that some means of extending the range of the system be employed. Of course, it is obvious that care must be taken to keep the area of interest in the original pickup within the range of the television system to avoid washed out highlights and muddy shadows.[11,12]

The circuits used for gray-scale compensation are either expanders or compressors. The type varies with the type of tube used in the film reproducing equipment. Circuits providing a response in accordance with a power law of less than unity are used with linear pickup devices such as the flying spot scanner in order to compensate for the high contrast of the final reproducing kinescope. Circuits expanding the highlights are used to overcome the compression introduced by pickup tubes such as the iconoscope and by the recording kinescope as well. Circuits expanding the shadows have been proposed for overcoming the compression of the lower tones by the toe of the sensitometric characteristic of the film stock. The BTL "Rooter" circuits[9] and the NBC "Orthogam" amplifier[10] are examples of such units.

The effect on the reproduced picture may be seen in Figs. 9 and 10. The former is a photograph of a televised image with no electrical compensation while the latter shows the results obtained with the same signal by employing electrical gray-scale compensation. Aperture compensation was not used in either case. Approximately 20% of the original video signal, representing the maximum "white" excursion, was stretched to comprise about 50% of the resulting corrected video signal, with the gradient increasing toward the peak of the "white" signals. Similarly about 10% of the "black" signal was stretched to 20% in the resultant, in order to compensate for the compression introduced by the film characteristic. Since the operation of the studio camera and the film reproducing equipment may both introduce gray-scale distortions which differ widely from the representative curves previously shown, it is difficult to establish an optimum characteristic for the circuit to be em-

Fig. 4. Kinescope recording, no compensation.

Fig. 5. Kinescope recording, excessive electrical aperture compensation.

Fig. 6. Television reproduction on overcompensated recording (shown in Fig. 5).

Fig. 7. Television reproduction of uncompensated recording (shown in Fig. 4).

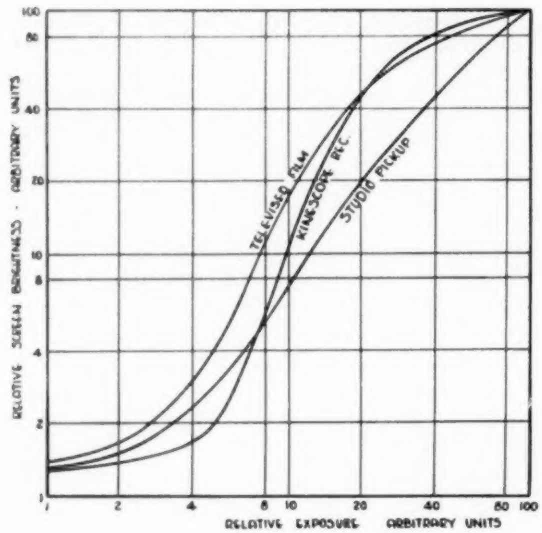


Fig. 8. Contrast rendition transfer characteristics of television system.

ployed at the recording position. It should be appreciated that such compensation may accentuate defects such as flare, shading and halo in a studio origination so that it is imperative for the operator at the camera control position to minimize such effects and for the program director to avoid calling for lighting which makes it necessary to tolerate such defects in order to get a picture at all.

One method of compensation recently proposed does not employ electronic circuits but depends upon photographic techniques. This method depends upon a well-known technique called "area masking" which was described in some detail at the Society's Spring Convention in New York.[5,13,14] It has the advantage of accomplishing both gray-scale compression and effective aperture correction in one process without an appreciable increase in noise. It does, however, have the disadvantage of requiring the preparation of a masking print from the negative and, therefore, requires evaluation as to its operational and economic feasibility. The results obtained can be judged from a comparison of Fig. 9 with Figs. 11 and 12, which show, respectively, the reproduction of a television signal from a normal-contrast subject: firstly, with no compensation and normal film processing; secondly, with no compensation but with a low-contrast print to keep the range of signals within the limits of the television system; and thirdly, with a print of low-contrast range prepared by the area masking process. The correction of the contrast range without destroying the fine detail is easily observed. The principal limitation of the method is in the introduction of edge effects which become objectionable when the compensation is carried to excess.

Kinescopes

The kinescope used in the recorder is far from perfect. In view of the importance of its performance to the overall result, a comprehensive program was aimed at uncovering the manner in which better performance could be achieved. Figure 13 shows the details of the tube which require consideration.

In order to examine the possibilities of realizing better performance, a large number of experimental tubes was constructed and subjected to careful measurements as well as tested in a recording setup. The most important variations tested to date as well as the results obtained are tabulated in Fig. 14. The performance of the experimental tubes is referred to the characteristics of the RCA Type 5WP-11, currently in production. It was suspected that light was dispersed in the phosphor itself thus increasing the size of the scanning spot and decreasing the effective aperture response. Three methods of reducing this effect were investigated. The first consisted in aluminizing the phosphor without the usual collodion backing. This permitted the aluminum to form light barriers between the crystals. As indicated in row B of Fig. 14, tubes made in this manner exhibited excessive grain, poor light output and were hard to drive since the penetration of the scanning beam was seriously reduced by the greater thickness of the aluminum layer. The second approach consisted in reducing the thickness of the phosphor deposited on the faceplate. As indicated in row C of the figure, some improvement in detail contrast was noted in these tubes; however, the major effect was an increase in light output since the thickness of the deposit was more nearly optimum for the potentials at which the tube is designed to operate. The third method consisted in mixing a small amount of light-absorbing material with the phosphor. In the experimental tubes finely divided carbon was used. It was found that the gain in fine-detail contrast was small, that the tubes exhibited serious graininess, and that the light output was appreciably reduced before any appreciable improvement in detail could be observed. The qualitative results are indicated in row D. Attempts were also made to reduce the flare light by decreasing the halation in the faceplate. With gray glass faceplates some improvement in detail contrast was observed and the general flare was decreased but the film exposure was excessively reduced when an effective improvement was obtained. The performance of these tubes is indicated in row E of the figure.

Tubes of greater length and with improved gun structures, row F, were tried in an effort to obtain a finer spot. It was concluded that the size of the electron beam was not limiting but that spreading of the spot in the phosphor and more especially halation in the faceplate were the major causes of loss in detail contrast and resultant loss in resolution. The major improvement obtained by increasing the length of the tubes, row G, was to decrease the deflection angle and thereby provide a more uniform focus. The same result was obtained by redesigning the deflection yoke although this introduced geometric distortion in the form of pincushion. This last effect can be corrected by suitable optical means.[11]

Tubes of larger diameter, row H, were built and tested in the hope that the larger image would permit the realization of improved detail. Since the beam current had to be increased to provide the same exposure of the film stock, it was found that little improvement in this respect was obtained. The effect of the phosphor grain was reduced and the image was more readily observed by the operator and, therefore, easier to monitor. However, the large size required to obtain a worth-while advantage resulted in cumbersome construction and did not appear to be warranted.

Since the screen brightness appears to limit the use of methods of reducing halation and since the P11 phosphor* saturates at a current density which is not sufficient to produce the desired

* The P11 phosphor referred to has a spectral energy characteristic peaking in the blue region, the maximum response occurring at a wavelength of approximately 4600 Angstrom units.

Fig. 9. Kinescope recording, no compensation.

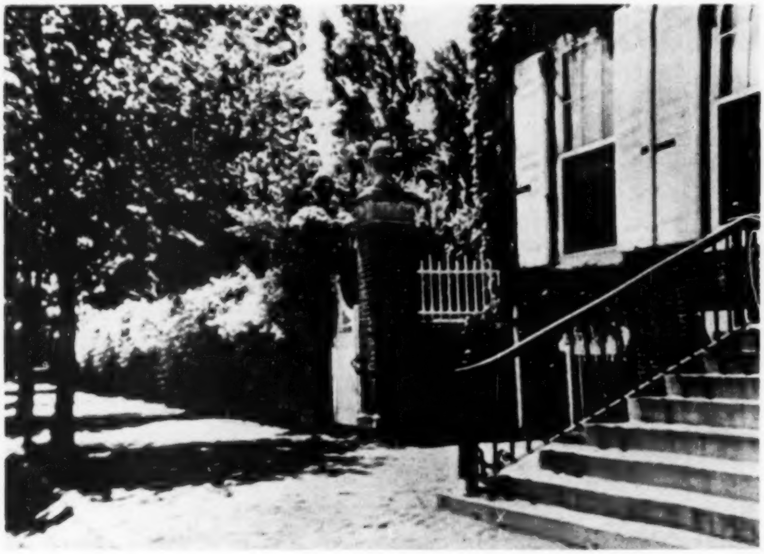


Fig. 10. Kinescope recording, electrical gray-scale compensation.

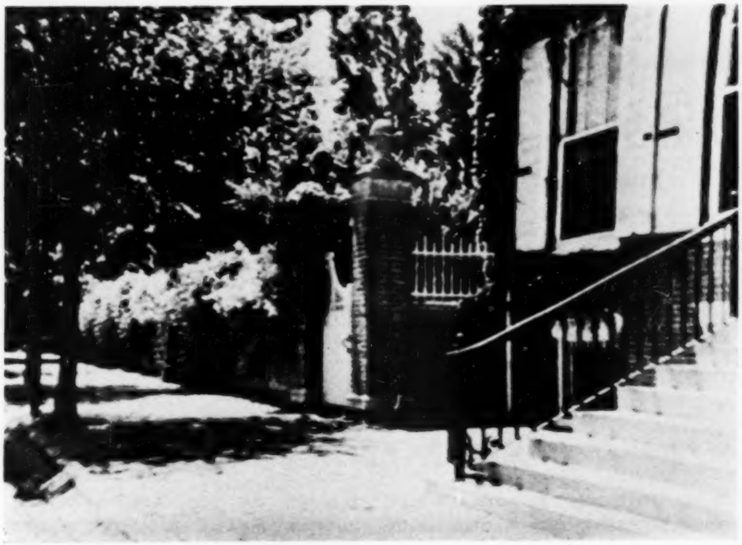


Fig. 11. Television reproduction of a low-contrast print.

Fig. 12. Television reproduction of an "area masked" print.

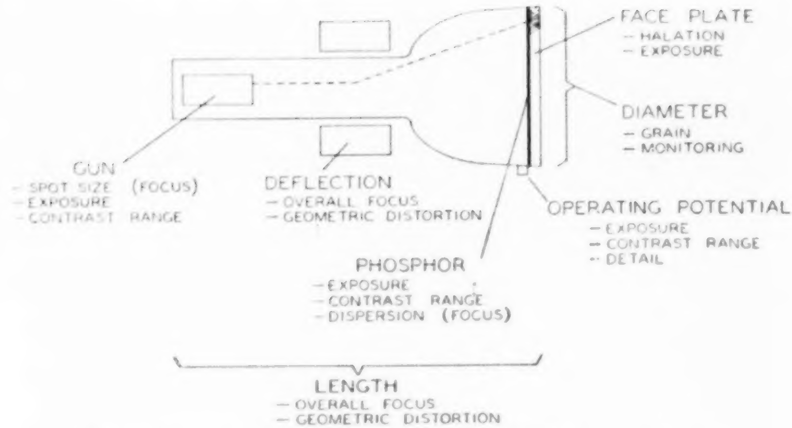


Fig. 13. Features of recording kinescope affecting recorded image.

highlight brightness at the present operating potential, it was decided to construct a tube operating at considerably higher voltage, row I. Experimental tubes similar to those used in theater television equipment but having screens of P11 phosphor were built and tested. The results were highly encouraging. The available exposure of the stock was increased several fold permitting the reconsideration of gray glass faceplates and possible reduction of the aperture in the camera lens. Tubes of this type are now being subjected to tests in order to determine the optimum operating potential, gun design and phosphor thickness.

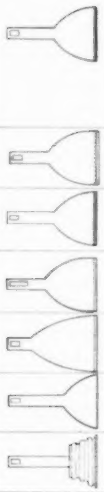
One method of increasing the effective exposure from the present kinescope consisted of applying a vertical deflection in the order of 20 mc to the scanning beam. This deflection was just sufficient to eliminate the appearance of scanning lines. Measurements indicated a gain in light output in the order of 2 to 1 by the application of this "spot wobble" technique.

Cameras

While high-quality lenses are employed in the camera, they are normally adjusted for optimum correction at infinite focus. In kinescope recording, they are used at relatively short distances and exhibit considerable curvature of the field. The effect can be partially corrected by the employment of a suitable portrait attachment.

One of the most serious defects which can be introduced by the camera is the displacement of the image on the film by vibration. This can completely destroy interlace and cause serious losses in detail. The transmission of energy to the light gun structure of the kinescope is apparently the major source of trouble. Good interlaced recordings have been obtained by isolating the camera and kinescope with proper shock mounts. Care must also be taken to avoid vibrations from other sources affecting the relative position of the kinescope and camera or from causing mechanical displacement of the gun structure in the kinescope.

The film transport mechanism can cause misregistration of the frame and thereby introduce jump into the recorded picture as well as aggravate the effects of shutter bar. The short pull-down cycle imposes severe mechanical problems in the design of this



	EXPERIMENTAL KINESCOPE	SPOT SIZE	FOCUS VS BRIGHTNESS	CORNER RESOLUTION	FLARE LIGHT HAZE	LIGHT OUTPUT AT USEFUL FOCUS	GRAY SCALE RANGE	DETAIL CONTRAST	REMARK
A	RCA TYPE 5WP11	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	
B	LESS COLLODION	NORMAL	NORMAL	NORMAL	SLIGHT IMPROVEMENT	LOW	ABOUT NORMAL	SOME IMPROVEMENT	EXCESSIVE GRAIN EXCESSIVE DRIVE REQUIRED
C	THIN SCREEN	NORMAL	NORMAL	NORMAL	SLIGHT IMPROVEMENT	APPROX 2:1	SOME IMPROVEMENT	SOME IMPROVEMENT	
D	CARBON IN PHOSPHOR	NORMAL	NORMAL	NORMAL	SOME IMPROVEMENT	LOW	ABOUT NORMAL	SOME IMPROVEMENT	EXCESSIVE GRAIN
E	GRAY GLASS FACE PLATE	NORMAL	NORMAL	NORMAL	SOME IMPROVEMENT	LOW	ABOUT NORMAL	RELATIVELY WORSE	
F	IMPROVED GUN	NORMAL	NORMAL	SOME IMPROVEMENT	NORMAL	NORMAL	NORMAL	NORMAL	
G	DECREASED DEFLECTION ANGLE	NORMAL	NORMAL	SOME IMPROVEMENT	NORMAL	NORMAL	NORMAL	NORMAL	
H	LARGE TUBE	NORMAL	NORMAL	NORMAL	NORMAL FOR FINE DETAIL	ABOUT NORMAL	ABOUT NORMAL		BETTER MONITORING
I	50 KV	UNDER INVESTIGATION							

Fig. 14. Tube variations tested, with results of tests.

mechanism and sometimes the motion of the film was not completely stopped before the shutter opened. This resulted in smearing of the television lines over this region of the image. These defects have been entirely eliminated in experimental equipment by the use of a modulated pressure pad and the redesign of the registration pins.

The methods currently employed to photograph the 60-field/sec image of the television system on the 24-frame film used in motion pictures all require that the television image be "spliced" at some point within the picture area.[18] When mechanical shutters are employed, an interval of several lines is required to complete the operation of opening and closing. During this interval, the rate at which the illumination increases and decreases must be carefully balanced so that a uniform exposure is obtained. When properly adjusted, the splice is invisible. When this balance is not obtained, the difference in exposure causes a fluttering or local flicker to appear in the vicinity of the "splice."

Instead of a mechanical shutter, it is possible to blank out the picture on the face of the kinescope by electronic means. Such an electronic shutter was successfully demonstrated several years ago. Recently, the technique was reinvestigated to determine the practical advantages and limitations which it offered. The realization of adequate precision in the timing devices necessary to produce the special blanking signal was not difficult to achieve. However, the stability and regulation required of all associated circuits appeared to be excessive since exact interlace must be obtained at all times. Small displacements of the raster not observable with a mechanical shutter appear as white or black horizontal streaks in the picture.

Moreover, the interruption of an image of this brightness for a relatively long period and at a 24-frame rate produces a flicker which makes it difficult to observe the image for any extended period of time and prevents continuous monitoring by the operator. In either case, precise adjustment and the application of proper mechanical or electrical shading to balance the exposure resulted in the elimination of such defects. The matter is more one of maintenance than of optimum performance.

Photographic Processes

The choice of currently available film stock suitable for kinescope recording is limited. High-speed negative emulsions are generally too grainy, especially for 16mm recordings, while fine-grain emulsions are usually confined to relatively slow-speed materials. With these, it is difficult to obtain a sufficient range of exposure due to the relatively low brightness of the kinescope. Care must, therefore, be exercised in the setting of the black level in order to avoid compression in the shadows since the stock is usually worked at lower than average densities while at the same time the highlights must be adjusted to realize the maximum exposure without phosphor saturation or spot defocusing. On Eastman Kodak Co. Type No. 7273 film stock, comparatively good results can be obtained by exposing to obtain densities of 0.2 and 1.2, respectively, with development to a control gamma of approximately unity. In general, current practices appear to be employing the available emulsions to the limit of their possibilities and little advantage seems likely to accrue from variations in processing parameters unless the exposure can be appreciably increased.

Because the available highlight brightness in the kinescope image at current densities less than saturation does not provide normal exposure of the recording stock, the operators frequently tend to overdrive the kinescope in order to obtain an apparent good contrast range on the negative. This tends to exaggerate any compression in the original signal and is probably the principal reason for the criticism leveled at the recording technique.

There are several different approaches to the recording, distribution and reproduction of kinescope recordings. The first and most direct approach employs a positive image on the face of the kinescope and produces a negative image on the recording stock. This negative may be televised, thus eliminating the losses involved in the printing process, or positive prints may be made from it for release to other stations. The former process may be used for local delay broadcasts or for cases where the time required to transport the original negative to the remote station can be tolerated and where only one such transmission is involved.

The second approach is to employ a positive image on the kinescope but to photograph this image on reversal stock. Good results have been obtained in this manner but the lack of positive prints for distribution makes its application limited as in the case of employing a direct negative for reproduction.

The third approach employs a negative image on the face of the kinescope, and provides a direct positive for reproduction over the television system. The film thus obtained is likely to be of low contrast and may not appear satisfactory for direct projection. However, good results have been obt- ed over the television system. The method is open to the objection that no release prints are available.

The fourth method is to photograph a negative image on the kinescope on reversal stock. The reversal negative thus obtained can then be used to produce release positive prints. Very poor results have been obtained with this technique.

Since prints for release should be positives to permit the insertion of local trailers and since such releases are necessary for all conditions except for network originations, it appears that the conventional method of photographing a positive kinescope image on normal stock offers the best practical solution.

The losses introduced by the printing process have also been investigated. Carefully measured negatives have been distributed to processing laboratories with requests for processing under usual conditions so that data relating to the differences between various printing methods might be obtained. Unfortunately, it has been difficult to obtain the full cooperation of sufficient laboratories to permit definite conclusions to be drawn. The effort is continuing and it is hoped that eventually it will be possible to recommend improvements in both printers and printing techniques.

For some time, the use of 35mm film has been suggested as a means of realizing greater detail in recordings. While this may prove to be practical for network usage where stations are equipped with 35mm television film projectors, it will be necessary to distribute release prints on 16mm film since many local stations operate with 16mm projectors and do not have 35mm facilities. Furthermore, even though most release prints are on acetate stock, local fire ordinances require special precautions when 35mm film is used to insure protection against the possible employment of nitrate film. It seems unlikely that such restrictions will be removed in the near future. It will, therefore, be necessary to accept the limitations on detail which the smaller film size imposes. While the difference in detail is significant, acceptable results can be obtained on 16mm film by minimizing the losses in the remainder of the system and by employing optimum electrical aperture correction. Fortunately, the emulsions are identical so that no further loss in gray-scale rendition is introduced.

Monitoring

It will be appreciated that the narrow range of the television system and the need to employ this range to the best advantage in exposing the film will require considerable precision in establishing brightness levels on the face of the kinescope. Visual observation is not sufficiently accurate for this purpose and monitoring the video signal applied to the recording kinescope does not measure actual brightness and is limited in the precision with which the observation of levels can be made on the associated oscilloscope displaying the video waveform. In order to provide a more reliable means of establishing the recording levels, a generator was developed which furnished a video signal in the form of a series of steps. This generator is, therefore, the electrical equivalent of a photographic density wedge. The overall amplitude of this signal is adjusted to fit the video range of the signal provided from a master control. The picture produced on the face of the kinescope is, therefore, a group of bars of varying brightness each of which represents a distinct video voltage level. The pattern on the face of the kinescope is picked up by a calibrated photocell and the output is displayed on an oscilloscope. The bars are arranged horizontally in order to minimize the effects of phosphor decay which would tend to average the brightness along a horizontal line if vertically disposed bars were employed.

Film Reproduction

In order to complete the review of the entire system, it is necessary to include the performance of the pickup tubes available for television film reproduction and the characteristics of the projectors associated with them.

The pickup tubes of current interest include the iconoscope, the image

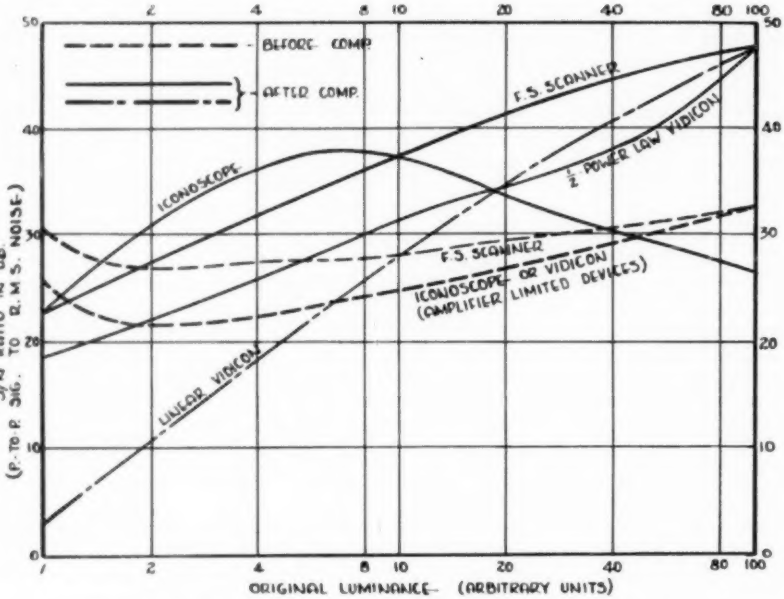


Fig. 15. Effect of gamma compensation on signal-to-noise ratio.

orthicon, the flying spot scanner and the vidicon. The gray-scale characteristics of these devices differ in several ways and affect the type of compensation that is inserted in the system. This aspect has been discussed previously at some length in several publications.[16,17] The noise characteristics of the several tubes differ so that the degree to which compensation may be employed to advantage also varies. The relative performance of several tubes as regards noise in the reproduced image may be estimated from the representative characteristics plotted in Fig. 15. It will be noted that a linear device such as a vidicon is seriously limited if the noise originates in the first amplifying stage. This limitation will be alleviated if the device can be made to have a power-law response of less than unity. Image orthicons of the presently available types have been employed as film pickup devices and are currently in use to some extent. Under present conditions the relatively narrow range over which these tubes can be operated without gray-scale distortion, the susceptibility to burning-in of fixed images and the rather critical adjustments required for satisfactory operation present problems which must be considered in evaluating their application to present-day operations. Therefore, although future developments may remove these difficulties, interest is currently directed toward the iconoscope and the flying spot scanner for this application.

The iconoscope is a storage device and as such, permits the use of projectors of conventional type since the storage permits the use of long pull-down cycles. However, best results are not obtained under such conditions and the use of long application times with short pull-down cycles has been shown capable of reducing such undesirable characteristics as shading and edge flare.

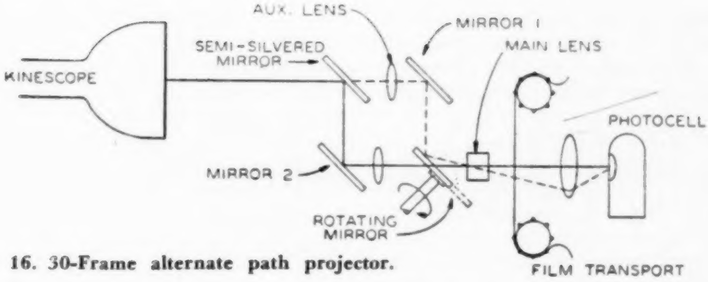


Fig. 16. 30-Frame alternate path projector.

Moreover, the performance can be further improved by the application of proper edge lighting and back lighting as well as circuitry to provide an essentially constant background signal level under wide changes in scene brightness.

The flying spot scanner does not make use of the storage principle and, therefore, requires the scanning spot to be maintained in proper register with the film at all times. The two types of projectors which have been suggested to accomplish this are either the fast pull-down projector, in which the film is pulled down in the television blanking interval, or the continuous projector, in which the film moves at a constant rate and proper registration is maintained by either optical or electrical displacement of the image of the scanning spot.

Several experimental models of fast pull-down projectors have been built. These devices have all been designed for 16mm film. Obviously the problems associated with minimizing the wear on both film and mechanical parts due to the high accelerations involved will require extensive life tests before the practicability of any design of a film transport mechanism can be evaluated. The ability of the mechanism to provide accurate registration in such a short pull-down time also presents mechanical problems. The results obtained on one model have been highly encouraging. After more than 400 passes through this model, no damage to the film sprocket holes was observed. Moreover, no perceptible increase in jump was observable with the SMPTE test film after more than 50 hours of operation. While these results must be confirmed by further operation over an extended period of time, it would seem that flying spot scanner operation with this type of projector is within the realm of possibility.

Continuous projectors are of two fundamental types: (1) those that allow the film motion to accomplish a portion of the vertical scanning and employ optical or electrical means to deflect the scanning raster to the proper position at the beginning of each scan; and (2) those that use continuously varying optical means to maintain registration of the raster and the film as the film moves.

The first type has been used in Europe where the 50-field television standard permits a relatively simple alternate positioning of the raster by running the film at a rate of 25 frames. For U.S. television standards, this would require a special 30-frame film. One version of such a projector is illustrated in Fig. 16. Since there are only two television fields for each film frame, only two positions of the scanning raster are required. The system shown employs mirrors to deflect the beam and provide the two alternate paths. Since the mirrors can be relatively large, a projection lens of high speed can be used. A projector of this type was built and tested and found to operate extremely well. Care must be taken to maintain

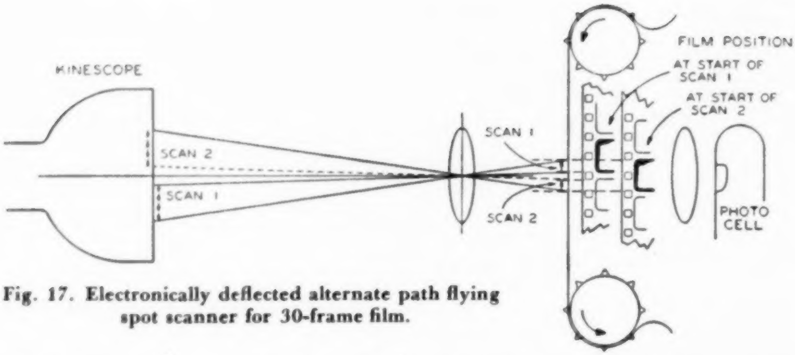


Fig. 17. Electronically deflected alternate path flying spot scanner for 30-frame film.

equal transmission over both of the paths to avoid flicker at a 30-cycle rate.

When 24-frame film is to be televised at a 60-field rate, it is necessary to scan one film frame with two television fields and the next with three. In a projector of either of the foregoing types, five alternate paths must be provided. In the multiple-lens case, this means a still further reduction of lens speed. In the second system, cams may be employed to position the unused mirror while the other is in use and held stationary. An experimental model of such a unit has been built but tests are not sufficiently advanced to permit an evaluation of its merits at this time.

Instead of shifting the effective position of the raster by interposing optical elements between the kinescope and the objective lens, it is possible to accomplish the same result by displacing the raster vertically on the face of the kinescope. The principle, as applied to 30-frame film, is illustrated in Fig. 17. It will be appreciated that extreme linearity of scanning and a minimum of geometric distortion must be achieved in order that the registration of successive fields be obtained. The system has also been tried for 24-frame film and U.S. Television Standards. The problem of registration is of the same order of magnitude as before but an additional problem of unequal duty cycle of various areas on the face of the kinescope is introduced due to the unavoidable overlapping between the displaced rasters. As the tube ages, objectionable flicker may be introduced should this produce unequal light output from the several areas.

Projectors in which moving optical systems have been employed to maintain constant registration with a moving film have been attempted for some time. These have employed rotating lens disks and drums, rotating prisms and rotating mirror systems. The first two systems require extreme precision in the optical elements, are inherently low in light efficiency and are difficult to compensate over the desired range of travel. The last system was originally developed by Meccau in Germany and produced satisfactory results although it was difficult to maintain proper adjustment. Recently this principle has been revived and appears to offer considerable promise of satisfactory and practical operation.

The promised improvements in film pickup equipment will considerably improve the results obtained from kinescope recordings as well as from normal film material by eliminating many of the defects present under current conditions, and by providing more stable and uniform characteristics, thereby reducing the variability injected by the continual adjustment in accordance with the operator's judgment.

Summary of Current Status

The present status of kinescope recording may be summarized as follows:

1. Good quality is possible with present equipment by careful control of the lighting and staging and by proper operation of both the studio camera and the film reproducing equipment. This imposes objectionable restrictions on programming but must be tolerated until further improvements can be realized.

2. Some improvement can be obtained by the use of electrical correcting circuits but care must be taken to avoid overemphasizing the defects in the original pickup.

3. Some improvement in kinescopes has been obtained. Current limitations are expected to be removed to some extent by the use of higher operating potentials.

4. Satisfactory camera mechanisms can be realized and either the mechanical or electronic shutters can be adjusted to eliminate visible shutter bar. The latter, however, introduces problems in maintenance and monitoring.

5. Better monitoring techniques can be employed. The use of a step function generator and a photocell monitor promises to provide greater uniformity and more precise exposure.

6. Present photographic processes appear to be capable of very little improvement under present conditions. An increase in kinescope brightness or the introduction of a new emulsion might make changes in processing desirable.

7. The photographic compensating technique known as "area masking" offers advantages but requires evaluation from the operational and economic standpoints.

8. Improved film pickup equipment offers the possibility of minimizing the losses introduced during reproduction.

Conclusion

It must be emphasized that the losses and distortions in the system are the summation of a number of individual deficiencies and that an improvement in one element may be masked by degradation contributed by the remainder of the process. No one element is responsible for the overall loss of detail or distortion of contrast so that many small improvements must be attained before an outstanding improvement is made in average reproductions. Until such time as these improvements can be included in the system, program directors and technical directors would be well advised to maintain a careful control over lighting, staging and camera operation if they expect acceptable quality to be realized in the recorded program.

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Discussion

Anon: Where on the response curve does the corrected mask fit on the chart that was shown for the response for the live studio 35mm film and the kinescope film?

P. J. Herbst: I don't get the question. Where, on which response curve is what?

Anon: There was one of the charts shown on the screen, one that showed the response for a live pickup for 35mm and for 16mm, and I just wondered where the masked area . . .

Mr. Herbst: Oh, you mean area masking, how much that improved it?

Anon: That's right.

Mr. Herbst: I'm sorry I hadn't understood. I would say this. I think that just from observation it brings it up to something; it'll bring a 16mm recording up to something that is not quite as good as the 35mm reproduction over the TV system.

Anon: In the interests of settling the question, which is the more authoritative source of technical information, the gossip columns or the proceedings of this learned Society? I would like to have you express something about the future of photographic kinescope recording vs. magnetic recording of the image.

Mr. Herbst: A magnetic recording would be fine if we knew how to do it.

Anon: You probably haven't been reading the Hollywood columns in the last couple of weeks, but it's supposed to be a reality.

Mr. Herbst: I haven't seen any of it yet. I'm sorry.

Anon: I wonder if we can still stay in business.

Mr. Herbst: I think, to answer your question, that unless someone has come out with magnetic heads and magnetic materials which are capable of much higher frequencies than we've gotten so far (and that may be possible), until that happens, I don't think that photographic kinescope recording will be abandoned.

F. N. Gillette: Regarding the question that was raised just a moment ago, is it really proper to consider this area-masking technique as a means of improving the response curve of the system? It's more a means of improving the tone values, isn't it?

Mr. Herbst: Yes, but it also improves the large-area tone values—in other words, it reduces them to a value which the system can handle. At the same time, it leaves the fine-detail contrast where it was. So, essentially it's exactly the same thing as increasing the gain at the higher frequencies. I think that Otto Schade's old paper some years ago pointed out that you could do that. It doesn't make any difference whether you do it electrically or photographically.

Dr. Gillette: But actually does it amount to an increase in fine-detail contrast in any region which was properly treated by the techniques previously used?

Mr. Herbst: Oh, yes, it is increased in every region. Look at it this way. The mask is merely a way of reducing in any given area the exposure which is given to the print. If you did the same thing by dodging in an enlargement you wouldn't reduce the detail contrast any. You would merely reduce the overall contrast between large areas. The result is an increase in detail contrast relative to large-area contrast in all ranges of the picture, not just in the highlights and in the shadows.

Anon: You mentioned earlier some improvements on iconoscope film chains. Is information on these improvements available?

Mr. Herbst: Well, we expect to have that out shortly.

Multichannel Magnetic Film Recording and Reproducing Unit

By C. C. DAVIS, J. G. FRAYNE and E. W. TEMPLIN

The multichannel magnetic film recorder and reproducer provides three 200-mil tracks in accordance with proposed ASA standard for 35mm film. The effective crosstalk between adjacent tracks approximates −60 db and flutter content does not exceed 0.05%. Complete recording and reproducing transmission equipment is housed in the recorder and associated base cabinet. The recording channels operate from a nominal input level of −30 dbm, and a reproduced output of +16 dbm is obtained from each of the reproducing channels. Monitoring of each channel is provided from a separate triple-track head.

THE COMBINATION magnetic recorder-reproducer described in this paper was developed to meet the needs of the motion picture industry for a high-quality triple-track magnetic recorder. The use of a triple-track recorder was anticipated by the industry in formulating the magnetic-track standards for 35mm sprocket-hole film, provision being made that one of the three tracks recorded in such a machine should correspond in position with that of a single track recorded in an ordinary magnetic-film recorder. In fact, the performance specifications for the triple-track machine, especially those which specified the crosstalk between adjacent tracks, proved to be a determining factor in the location of the single track in the regular motion picture production magnetic recorder. The final triple-track standards as adopted by the Society's Sound Committee and which are now being considered for standardization by ASA are shown in Fig. 1. Reference to this figure will show that three 200-mil tracks are provided with a separation of 150 mils between tracks, the edges of the outside tracks being 50 mils from the sprocket holes. The proposed standard calls for a crosstalk figure between adjacent tracks of at least −50 db.

At the time of the formulation of the track standards, it was thought that the −50 db value of crosstalk would be satisfactory for the then intended uses of the triple-track recorder. However, as the industry began to use this new medium, the demand for a greater reduction of crosstalk became imme-

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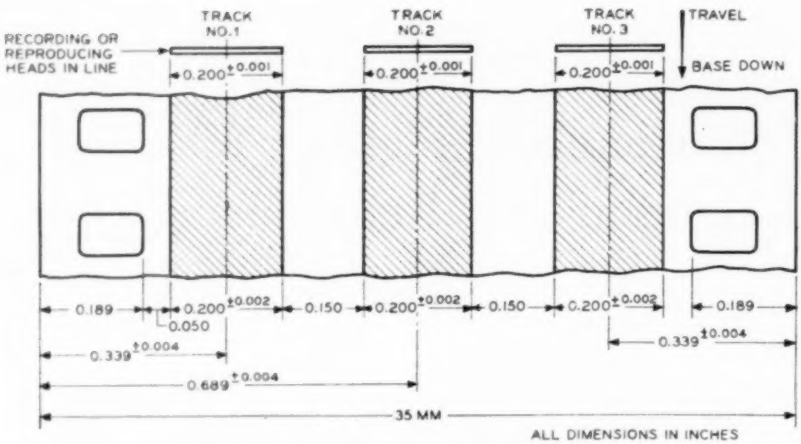

Fig. 1. Triple-track magnetic specifications.

diately evident and, as will be described later in this paper, means have been found for obtaining a crosstalk figure of approximately −60 db at 1000 cycles on a regular production basis. Exhaustive listening tests have shown that with this amount of crosstalk at 1000 cycles, no audible sound is heard in any track from a fully modulated signal in an adjacent track, whereas with the original value of −50 db, audible crosstalk is very much in evidence. If completely unrelated sound recordings are to be made on the three individual tracks, it seems highly necessary that a successful triple-track magnetic recorder meet the −60-db cancellation figure.

The intended uses for this type of magnetic recorder include the multichannel scoring operation in which this single machine would replace three existing single-channel recorders with the attendant economy in film usage and in manpower, as well as provide a much greater convenience in operation. A second major use of the triple-track recorder is that of providing storage of three individual tracks on a single film, thus providing a marked saving in vault space. These three tracks could be entirely unrelated or they could be used, for example, for storing dialogue, music and effects tracks on a single film. Other uses, of course, will be found particularly in the re-recording operations as the studios get more familiar with the possibilities of this type of recorder.

In order to facilitate the early introduction of this new recorder to the industry, it was decided to utilize the basic mechanism of the RA-1251 Re-recorder[1] which has had such wide acceptance in the industry for both photographic and magnetic re-recording. In order to accommodate a triple-track head providing three recording heads in line and locating them in a low-flutter film path, a double flywheel drive was substituted for the customary single unit. Two complete triple-track heads, one used primarily for recording and the second for monitoring or playback, are mounted in the film path between the two impedance drums mounted on the separate flywheel shafts. The arrangement of the film path and location of the two triple-track heads are shown in Fig. 2. It will be noted that the elements of the Davis Drive, pre-

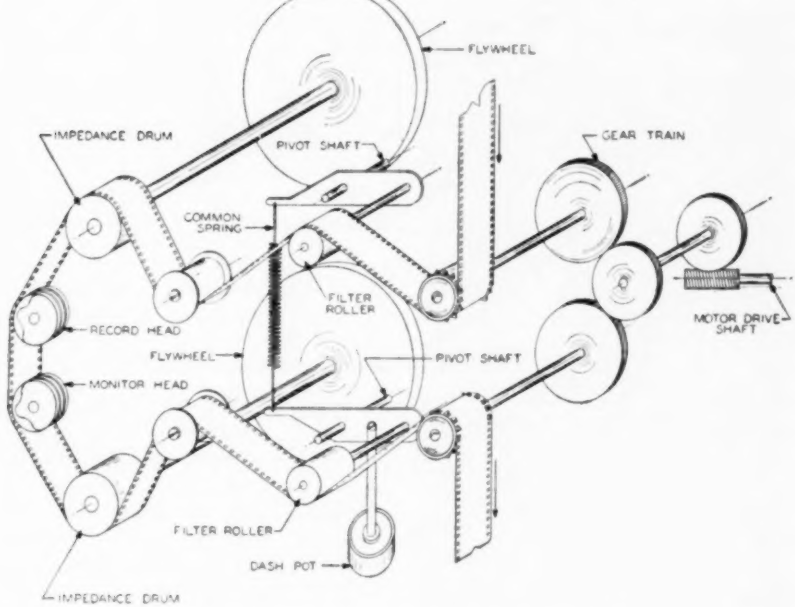

Fig. 2. Triple-track recorder film path schematic.

viously employed in the RA-1251, are retained. The single flywheel is removed, a new subassembly is substituted which carries the two individual flywheels, the mounting for the triple-track heads and a Permalloy shield box to isolate the heads as far as possible from magnetic pickup of extraneous fields. The combined moment of inertia of the two flywheels approximates that of the single flywheel, so that the natural period of the filtered film path remains essentially the same. The performance of this drive from a flutter standpoint is quite comparable to that of the RA-1251 Re-recorder when set up originally for photographic purposes. The total rms flutter for an average machine amounts to approximately 0.05% based on flutter frequency rates ranging from 2 to 200 cycles, the flutter at any given rate not exceeding 0.03% rms.

Figure 3 shows an electrical analogue of the film-drive filter mechanism, the components being designated below the illustration.

The basic elements of this circuit were previously shown to illustrate the double-arm or tight-loop filter mechanism for a photographic film recorder.[2] At that time an explanation was offered for the action of the common spring, C_1 and the double-sprocket drive, S_1 and S_2, including the general characteristics and attenuation curves of flutter disturbance originating in either or both of the sprockets.

The present circuit shows the addition of six elements which represent the additional flywheel and the significant items associated with the film passage over the magnetic heads. While six elements have been added, the film-filter performance remains substantially

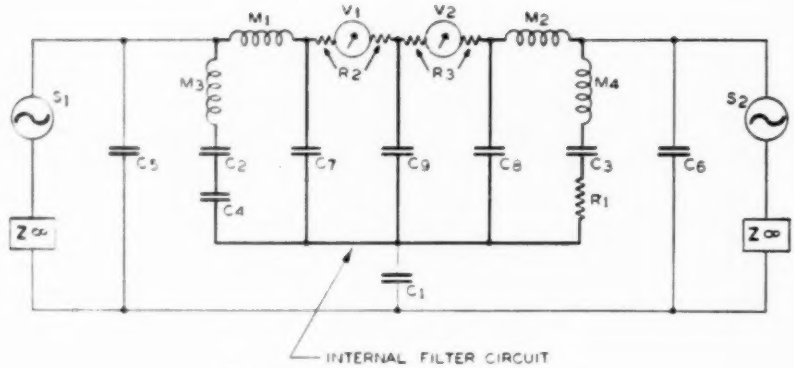

Fig. 3. Film-drive electrical analogue.

M_1 & M_2, Inertia of flywheels
M_3 & M_4, Inertia of upper & lower filter arms
C_1, Compliance of spring common to both arms
C_2 & C_3, Compliance of arms when moving together
C_4, Compliance of arm-positioning spring
C_5 & C_6, Compliance of film between flywheels & sprockets
C_7 & C_8, Compliance of film between flywheels & heads
C_9, Compliance of film between heads
S_1 & S_2, Upper & lower film drive sprockets
R_1, Resistance of dashpot damper
R_2 & R_3, Resistance of film over heads
V_1 & V_2, Reference film velocity at heads

unchanged from a single-flywheel type. This is because the elements C_7, C_8 & C_9 and R_2 & R_3 represent relatively small magnitudes, and M_1 & M_2 tend to become a single flywheel as these elements decrease in value. C_7, C_8 & C_9 are short, stiff lengths of film and, therefore, constitute small values of compliance. Likewise, R_2 & R_3, representing the effective damping resistance of the film friction over the heads, have relatively small values. This results from the well-known characteristic of solid or sliding friction acting at considerable velocity, as compared to viscous friction, because of their differences in force-velocity characteristics.[3] This may be illustrated by removing the dashpot, R_1, whereby the small remaining amount of damping caused by film friction permits highly undamped oscillation of the filter arms following a disturbance.

The displacing force created by film friction over the magnetic heads is offset by an adjustable spring, C_4. By this means the filter arms can be maintained in their correct operating positions in spite of large differences in the frictional coefficient of various film samples.

In the present design, forward-running speed of 90 ft/min is provided and the customary high-speed rewind is retained. For special applications where reverse operation at standard speed is required, a double torque-motor drive will be furnished for each film-spool spindle. A footage counter located in the central angle bracket is an added feature of the triple-track recorder.

The associated transmission equipment providing for three complete recording channels and three complete reproducing channels, operating at a nominal recording input level of −30 dbm and reproducing an output level

of +16 dbm, is housed in both the upper section of the recorder cabinet and in the associated base cabinet, as will be observed from Fig. 4. This provides for a maximum economy in recording-room space as well as in all the facilities and controls needed for operation of a triple-track machine. Complete details of the recording and reproducing transmission circuits and controls are described later in the paper.

Triple-Track Magnetic Head

The triple-track RA-1508 Magnetic Head shown in Fig. 5 is based on construction principles used in single-track heads previously described.[4] Basically, it is a ring type with two stacks of Permalloy laminations cemented in the divided halves of a hollow ring. This machined brass ring provides accurate reference surfaces for the otherwise irregular dimensions of the pile-up of laminations. These serve as a foundation for the manufacture of identical units which are combined into multitrack heads exhibiting close tolerances relative to track placement and azimuth alignment as a group. Thus, no individual adjustment is required for azimuth or track adjustment. The groups comprising the recording and reproducing heads are placed on a mounting bracket which provides facilities for adjusting the record and reproduce heads as units. The film is aligned with the entire assembly by an adjustable guide-roller as in the original photographic machine.

Interference or crosstalk in multitrack magnetic recorders, wherein the tracks are recorded simultaneously in line across the magnetic medium, results mainly from the fact that several heads lie side by side, separated by incomplete shielding since a considerable portion of the heads must be exposed to contact the recording medium. This type of crosstalk may be referred to as electrical because it evidences itself without the presence of any recording medium. It is the source of troublesome crosstalk

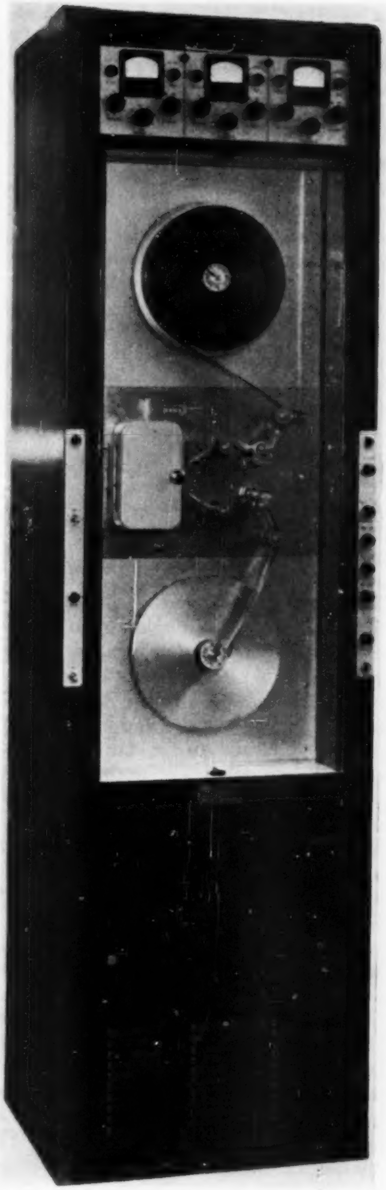

Fig. 4. Front view of RA-1506-A triple-track recorder.

in program material. A close phase relationship may be shown to exist between the original recorded track and the track produced by the induced flux in the adjacent head. Another form of crosstalk exists only at low frequencies or long wavelengths and normally is not a source of trouble in program material because of ear characteristics and the energy distribution of speech and music. It occurs when the recorded wavelength becomes comparable to the distance between tracks and the fringing flux becomes well defined and of such intensity in the adjacent track area as to constitute interfering crosstalk.

Special means have been incorporated in the recording- and reproducing-head assemblies to reduce crosstalk among the three heads. These consist of small magnetic paths introduced diagonally between one-half of each magnetic head and the corresponding opposite half of the adjacent head, and of such proportions and phase relationship as to cancel effectively the crosstalk leakage from one head to the other. These substantially decouple the two heads electrically or magnetically and are referred to as decouplers. In the case of a triple-track head only two decouplers are required since their action is, for all practical purposes, reversible. They handle relatively small amounts of flux and do not alter the normal characteristics of the recording and reproducing heads or the overall system in any way.

Without the application of decouplers, heads similar to those described evidence crosstalk interference of about −45 db. This refers to the ratio of crosstalk induced from a fully modulated signal in an adjacent track relative to a fully modulated signal in the track in question. While experiment has shown that crosstalk values better than −50 db may be obtained by increased shielding, particularly of such form as to compartment the tracks on both sides of the film, this method presents threading difficulties and, as previously stated, values considerably better than −50 db are necessary for general professional use. Therefore, the decoupler method has been developed and values of at least −60 db are obtained at 1000 cycles.

While a value of approximately −60 db of crosstalk at 1000 cycles has been obtained in this design, it will be noted from reference to Curve 1 of Fig. 6 that although the crosstalk stays appreciably constant from 150 to 3000 cycles, it rises to a value of about −45 db at 50 cycles and −48 db at 10,000 cycles. The increase at the low frequencies has been discussed above. The increase at the high frequencies simply reflects the closer coupling between adjacent heads at the high-frequency end of the spectrum. In Curve 2 of Fig. 6, the 40-db ear-weighting characteristic has been added to the experimental data used in Curve 1 and it is obvious that with this correction the effective crosstalk at low frequencies is well below audibility. Many listening tests with a wide variety of recorded material confirmed the selection of 1000 cycles as a suitable frequency for adjustment of the decouplers and for the attainment of −60 db at this frequency as a guarantee against any audible crosstalk in the recording audio spectrum.

The decouplers consist of several small strips of Permalloy extending diagonally from a point near the recording gap of one head to a similar point on the adjacent head. A small air gap at either end is adjusted for optimum operating conditions with the help of a wave-analyzer, after which the decouplers are locked in place.

The individual heads are separated by a double thickness of magnetic shielding material to reduce hum pickup from external sources. The complete head assembly is enclosed in a box of heavy magnetic material, the front half being hinged to allow access for threading.

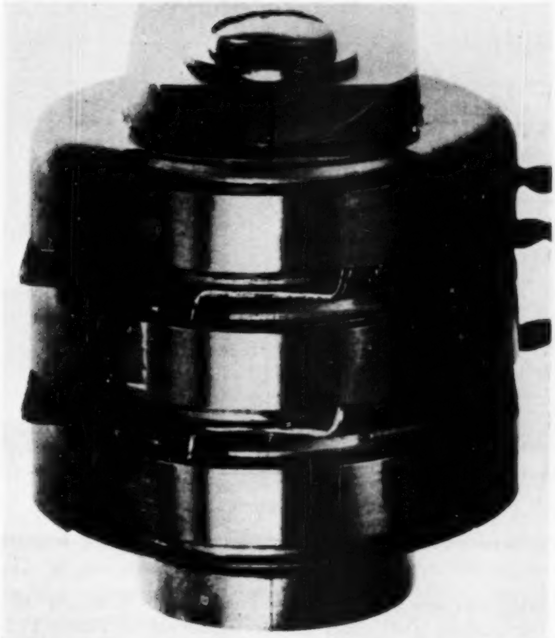

Fig. 5. RA-1508-A triple magnetic head.

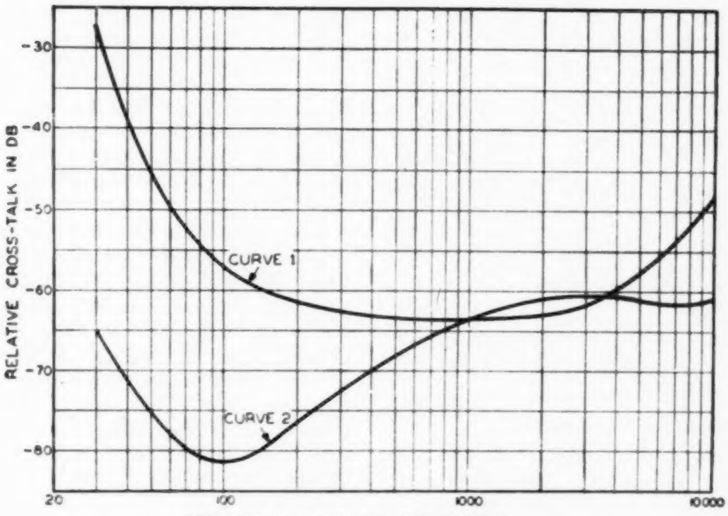

Fig. 6. Crosstalk as a function of frequency.

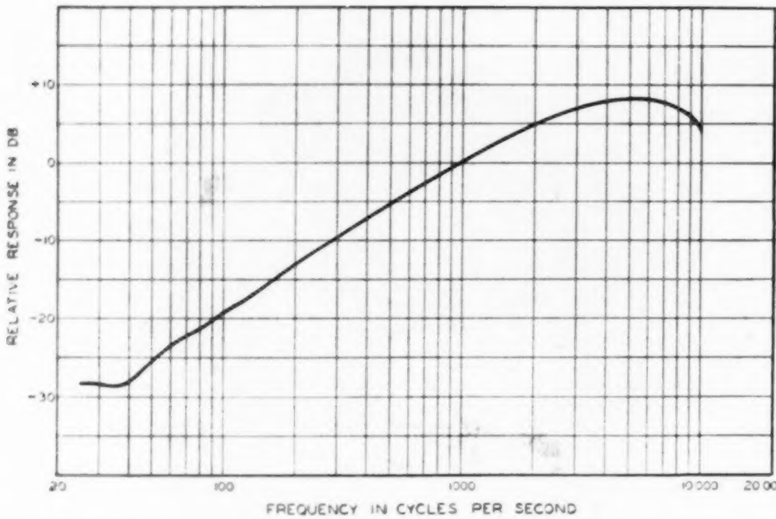

Fig. 7. Frequency-response characteristics of triple-track magnetic head.

To avoid abrupt changes in the track and shield relationship, the edges of the individual shields are especially contoured. This minimizes cyclic amplitude variations in the useful low-frequency-response characteristic. These may otherwise occur at scanning frequencies whose half-wavelengths effectively encounter abrupt changes in magnetic conditions. In this same connection, the departure from a normal 6-db/octave reproducing characteristic lies below the useful frequency range because of the generous film wrap and physical size of the heads.[5] Furthermore, these conditions promote long head life.

The frequency-response characteristic of a typical RA-1508-type head is shown in Fig. 7.

Transmission Equipment

Transmission components and their circuit arrangement have been established after considerable discussion of the general requirements for such equipment with major-studio sound personnel. The cabinet contains all transmission components, including 115-v, a-c power supplies, for operating directly from three mixer outputs when used as a recorder, and for operating into three high-level mixer inputs or power amplifiers when used as a re-recorder, reproducer or playback unit. Since these three transmission channels must be used simultaneously, special care must be taken to maintain the high degree of interchannel isolation provided by the magnetic heads.

When used as a recorder it operates at a nominal signal input of -30 dbm which permits considerable separation from the mixers without line-noise difficulties. It also furnishes direct monitor from each channel at a level of $+16$ dbm which is sufficient for operation directly into a small monitor speaker or through power amplifiers to a larger horn system. If the mixer operator will monitor from only one channel at a time, leaving to the recordist the responsibility for monitoring all channels simultaneously from the

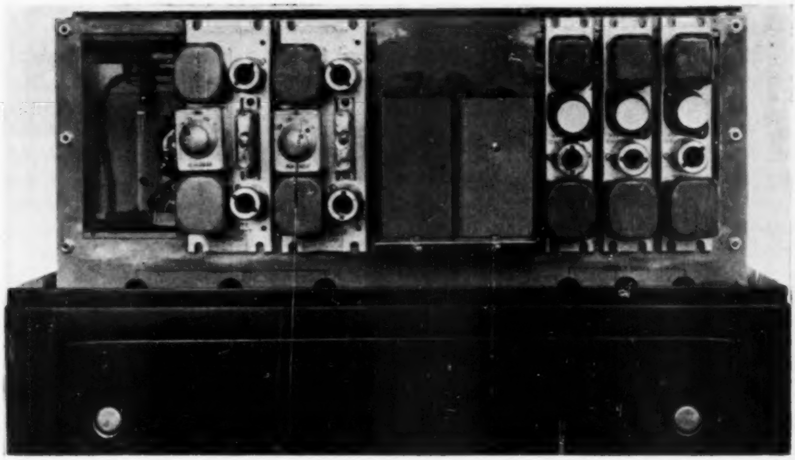

Fig. 8. Plug-in arrangement of amplifiers.

film, he may switch the input of his speaker system to any one of the three +16-dbm direct-monitor circuits. However, if he wishes to monitor two or more channels simultaneously, these may be combined as desired from low-level (−30-dbm) monitor circuits which are also provided. These are bridged from the high-level circuits with sufficient loss such that when combined they will not detract from the 60-dbm isolation figure provided by the heads. It is expected that the mixer operator will not monitor from the film because of the fractional-second delay required for the film to move between the record- and monitor-head positions.

When used as a re-recorder or reproducer, an output from the film of +16 dbm on each channel is provided through the same output circuit as is used for the direct monitor during recording.

The requirement that the three complete recording-reproducing systems, including power supply, be contained within the cabinet calls for special consideration of components and mounting arrangements. Three amplifiers are provided in each channel — one for recording, one for reproducing and an output amplifier used alternatively for direct monitoring or reproducing. For both the recording and reproducing amplifiers the compact RA-1474, as used in the latest Western Electric portable magnetic recording systems, is used.[6] This amplifier uses two miniature 12AY7 vacuum tubes with push-pull output of +22 dbm for 1% distortion. A feature of the amplifier is a plug-in unit which connects to two of the internal high-impedance circuits and provides for gain adjustment in the range from 40 db to 70 db and equalization as required for the particular application. As used in the recording amplifier, the plug-in unit reduces the gain to 48 db and in addition provides a low-frequency pre-equalizer which is used if this equalization has not already been inserted in the mixer circuits preceding this equipment. This pre-equalizer has approximately 4 db of boost at 60 cycle/sec and is complementary to the low-frequency shelf in the reproducing equalizer. In combination, the low-frequency pre- and post-equalizers provide a flat charac-

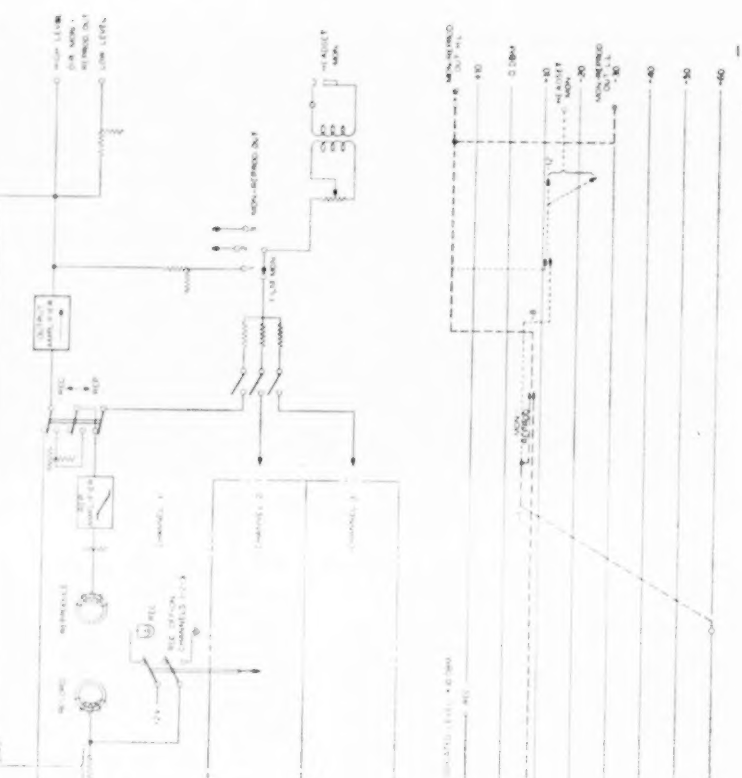

Fig. 9. Simplified block schematic and level diagram. Note: Levels shown are for 400 cycle/sec signal recorded at 100% modulation.

teristic at low frequencies and reduce the effect of power-line interference on the overall signal-to-noise ratio.

In the reproducing-amplifier application, the plug-in unit provides the required 6-db/octave characteristic with the low-frequency shelf as described above, plus a high-frequency shelf compensating for scanning and demagnetization losses.

A new amplifier has been designed to meet the requirement for the direct-monitor and reproducing output amplifier where less gain and greater power output are required than are provided in the RA-1474 described above. As used in this equipment it has a gain of 24 db and an output of +24 dbm with 1% total harmonic distortion. It is also expected that it will have general application as a 600-ohm-line amplifier and a zero-gain bridging amplifier. It is a single-stage push-pull unit using one miniature 12AU7 vacuum tube.

Both types of amplifiers have been equipped with new-type miniature plugs. This permits ready removal or replacement of any amplifier for maintenance or test at a bench position. Separate plugs at opposite ends of the amplifier provide for optimum segregation of low- and high-level circuits throughout the equipment, thus minimizing noise and crosstalk interference.

Figure 8 shows both types of amplifiers in their mountings. Also shown are the slotted guides in the mounting panel which insure registration of the plugs and receptacles. The complete mounting panel for the group of amplifiers is floated, thus making unnecessary the separate isolation of each unit.

The high-frequency bias for the three channels is supplied from one 60-kc-bias oscillator. This eliminates the possibility of audiofrequency beating which could occur with the interaction of three separate oscillators operating at slightly different frequencies. A distribution network from the oscillator output to the three recording-head circuits provides 70 db or more isolation below 6000 cycle/sec for the audiofrequency signals of the three channels which would otherwise be coupled together by the common oscillator supply.

The amplifiers are powered from the RA-1479-type power units as used in the previously described portable recording system.[6] One power unit handles the six record-reproduce amplifiers and the other handles the three output amplifiers. The bias oscillator contains its own separate power supply.

A simplified block-schematic and level diagram of the complete system are shown in Fig. 9. For recording applications, the nominal −30-dbm signal level is received from the mixer and the recording attenuator is adjusted to establish 3% total distortion from the reproduced film for 100% modulation. This normally is obtained with a level of +10 dbm at the recording amplifier output at which point the volume indicator and direct-monitor circuit are bridged. A series network in the head circuit forms the load for the recording amplifier. It also provides high-frequency pre-equalization in five 1-db steps so that with the fixed equalization in the reproducing amplifier a flat overall response is obtained. A 60-kc suppression filter prevents the bias signal from feeding back to the volume-indicator and direct-monitor circuits.

The direct-monitor circuit also contains a low-frequency postequalizer compensating for that equalization introduced earlier in the recording circuit or in the mixer. Under recording conditions it operates into the 24-db-gain output amplifier to provide a flat overall response to the mixer at a 100% modulation level of +16 dbm. Switching arrangements in the volume-indicator circuit permit the meter to be used alternatively for checking levels at the recording-amplifier output, the monitor-reproduce-amplifier output under either

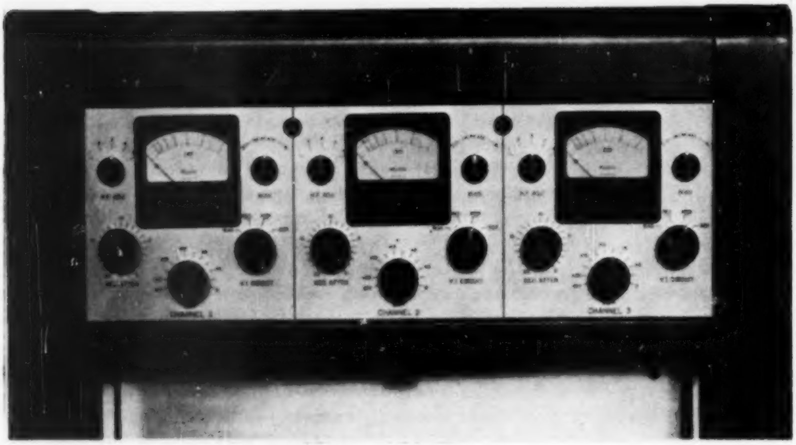

Fig. 10. Control panel.

recording or reproducing conditions and also for measurement of bias current.

The recordist monitors by headset from the output of the three reproducing amplifiers. Normally, if all three channels are being used, he will listen to them simultaneously. In the event any trouble occurs, or for any other reason, he can listen to each one individually or to any combination by operation of the separate cutoff switches. Since these switches are in only the reproducing circuit, their operation will in no way affect the recording. He can also compare the reproduced output from any one channel with the corresponding direct-monitor signal by operation of his monitor-selection switch.

Under reproducing conditions the 24-db-gain output amplifiers are switched to the output of the reproducing amplifiers to provide the +16-dbm output level and the volume indicators are connected across these output circuits.

To prevent the possibility of inadvertent application of the bias- and recording-circuit signal to the film under reproducing conditions, a separate record-reproduce switch operating on all three channels is provided. In the recording position the record and bias circuits are connected through to the head and a red warning light appears on the front panel. In the reproduce position all three record heads are shorted, thus preventing the application of either bias or audio signals.

The principal recording-reproducing operating controls are contained on the front panel covering the upper equipment space. As shown in Fig. 10, the controls for the three channels are identical and are grouped separately. These controls include, for each channel, Record Attentuator, High-Frequency Equalization, Bias Current, Volume-Indicator Meter and Meter-Circuit Selection. Other controls, including those associated with headset monitor and the drive motor, are mounted on either side of the center section of the cabinet.

Performance

The overall performance of the equipment amply meets the requirements for recording and reproducing equipment in major studios. Overall crosstalk isolation between channels, including

heads and all associated circuits, has been maintained at approximately 60 db through the critical middle range of the frequency spectrum.

Based on the allowable 3% total distortion for the complete recorder-reproducer system, the overall signal-to-noise ratio is maintained at 55 db to 58 db, unweighted. The overall frequency-response characteristic is essentially flat over the frequency range from 50 to 8,000 cycles.

Demonstration

A demonstration film has been prepared to show some of the operating characteristics and intended usage of this recorder. In the first part of the film three separate recordings of organ music, boys' choir and dialogue, respectively, are laid down on the three tracks. By switching outputs from the three heads to a single reproducing horn system, the high quality of each recording as well as the lack of interference among associated tracks may be observed. To emphasize further the low-level crosstalk conditions, the center track later in the reel carries no modulation, but the side tracks are heavily modulated. Switching from either of these tracks to the center one reveals no audible evidence of crosstalk.

Conclusion

The machine described in this paper permits the recording of three high-quality magnetic tracks on 35mm film, each one being comparable in quality to that of a single track on 35mm. The residual crosstalk value of −60 db gives, in effect, complete isolation of each track from the adjacent ones, thereby permitting the recording of completely unrelated material on any track. The success of the first units of this machine under studio operating condition presages their wide adoption in the near future for scoring, re-recording and film-storage purposes.

Acknowledgments

The authors wish to express their thanks to the other members of the Westrex engineering staff who have contributed to the success of this development. We wish to express thanks particularly to G. R. Crane for the mechanical design of the double flywheel drive, to A. L. Holcomb for the "packaging" of the electronic components, to H. R. Roglin for the testing and alignment of the magnetic heads and to P. F. Thomas for his painstaking testing of the first model of this recorder shown at the Society's Convention at Hollywood, Calif.

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Discussion

John G. Frayne: Before running the demonstration films, which are recorded in such a manner as to illustrate the effective reduction in crosstalk between tracks, I would like to express the thanks of the authors to the engineering and laboratory staff at Westrex Corporation, Hollywood Division, for their invaluable cooperation and assistance in this project. The credit for the invention of the decouplers goes to my colleague, C. C. Davis, and a U.S. patent application has been made in his name for this invention. The Westrex Corporation is pleased to

make this information public since it will undoubtedly stimulate constructive thinking on the part of others and thus will eventually aid in the improvement of the magnetic-recording art.

John P. Livadary: In the Columbia Pictures Sound Department we have been using multitrack magnetic films since November 1950 and we have accumulated a lot of experience concerning the method of compensating for losses in the magnetic re-recording link used in our dubbing operations.

To make it possible to reproduce the same film satisfactorily on any three-track channel, we found it necessary to standardize on the equalization of the reproducing circuits. This, in turn, has resulted in dividing the overall compensation for magnetic losses in two, and in equalizing for part of these losses in the recording and part in the reproducing circuits.

Consistent with this thought, we developed our own standard magnetic frequency film which we use to calibrate the reproducing circuits, the recording circuits being adjusted to achieve a one-to-one overall transfer which is desirable for re-recording purposes.

We have also been using electronic feedback means for the decoupling of crosstalk between adjacent magnetic heads with reasonable satisfaction since November 1950.

L. L. Ryder: One further contribution is that possibly, if the heads are moved a slight distance further away from the drums that may exist on some of the machines, you can still retain the high quality of movement which is desired and get away from a large part of the head wear. We have replaced one or two heads in our work since the advent of magnetic recording. I have in operation at Ryder Services a head which has been operating every day for about two years. It is still not worn out. The angle of approach of the film to the head and the angle of recession of the film may contribute quite a bit to the head wear.

C. E. Hittle: Since our good friend Dr. Frayne of Westrex has volunteered to provide us with information relative to the design of their equipment, as long as their design is covered by patent or patent applications, I have a question to ask relative to the design of their drum assembly, particularly pertaining to the design of the flywheels which they are using on their twin-drum system. Are they of equal mass, weight and size?

Dr. Frayne: Yes, they're identical as far as we know. The combined moment of inertia of the two flywheels is practically the same as the moment of inertia of the single flywheel on the RA1251 re-recorder. That was done so we could retain the same filter components.

M. Rettinger: I would like to ask Mr. Livadary if his electronic decoupling circuit provides crosstalk reduction equal to what was demonstrated this afternoon?

Mr. Livadary: About nine months ago we gave a demonstration, similar to the one given today by Westrex, in which we ran three tracks and cut off each track in turn to demonstrate the amount of leakage which existed. Our measured values of crosstalk suppression at 400 cycles were of the order of about 60 db to 62 db between any two adjacent tracks. At higher frequencies this figure was slightly lower. However, according to our experience to date, having dubbed about 1,000,000 ft of released footage on multitrack magnetic film, we haven't had a single crosstalk problem to cope with, and our decoupling methods have been satisfactory for our work.

Dr. Frayne: When John called me up and told me about this I asked him how it worked. He said that it was mounted in a little black box and that he could not divulge the details.

Mr. Livadary: I regret to reply to Dr. Frayne that this particular method was indeed in a black box at that time and I was more or less on a spot because we were in the process of securing patents which made it difficult to discuss this matter.

Magnetic Sound Track Placement

By LOREN L. RYDER and BRUCE H. DENNEY

This paper sets forth technical data indicating that in magnetic recording on 35mm film, high sprocket-hole modulation is encountered in the area between 50 and 100 mils from the sprocket holes. The paper suggests a change in the proposed ASA standard for 35mm sound track placement.

THIS PAPER is presented after a careful consideration of the present proposed ASA standard for 17½mm and 35mm magnetic sound track placement, Fig. 1. In the opinion of the writers there are two basic reasons why this proposal should not be accepted.

1. Recent tests show a very high percentage of sprocket-hole modulation in the sound track area close to the sprocket holes.

2. The present proposal was prepared prior to active editing of magnetic film and does not adequately meet editorial requirements.

Sprocket-Hole Modulation

The sprocket-hole modulation under consideration is a 96-cycle modulation of the sound signal. In magnetic recording and reproducing this effect is largely an amplitude modulation. It takes place in both recording and reproduction and usually is additive. It is the result of a varying contact and/or lack of contact of the magnetic head with the magnetic coating of the film. There are two primary causes for this variation in contact. During punching of the sprocket holes there is a deformation of the film in the vicinity of the sprocket holes that prevents uniform contact. In winding the film around a drum there is a polygonal effect due to the weakening of the film at the point of punching.

Tests made at Paramount indicate that experts are conscious of about 2% sprocket-hole modulation, that almost anyone will observe 5% and that the distortion becomes quite obvious at 8% to 10%.

A series of tests was made with record-reproduce head widths of 250 mils, 200 mils, 150 mils, 50 mils and a 50-mil head with a land so as to simulate contact of a 250-mil head. Each of these heads was tested at several distances from the sprocket holes. All of these tests were made with full-coated 3-M 35mm magnetic film on a Westrex RA-1231 recorder modified for magnetic recording-reproduction. This is a single drum recorder with the head in the drum. Comparable results were obtained both for the condition of compliant head and fixed head.

Presented on October 18, 1951, at the Society's Convention at Hollywood, Calif., by Loren L. Ryder and Bruce H. Denney, Paramount Pictures Corporation, 5451 Marathon St., Hollywood 38, Calif.

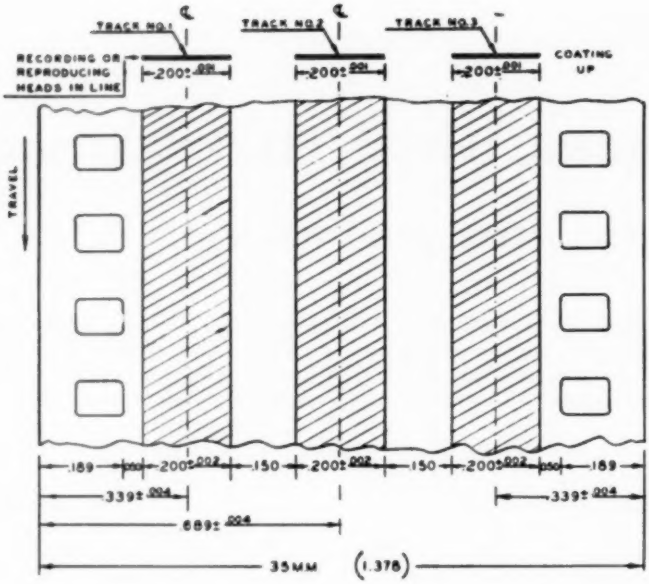


Fig. 1. Proposed American Standard for Magnetic Sound Track Placement. (See Fig. 5A for new recommendation.)

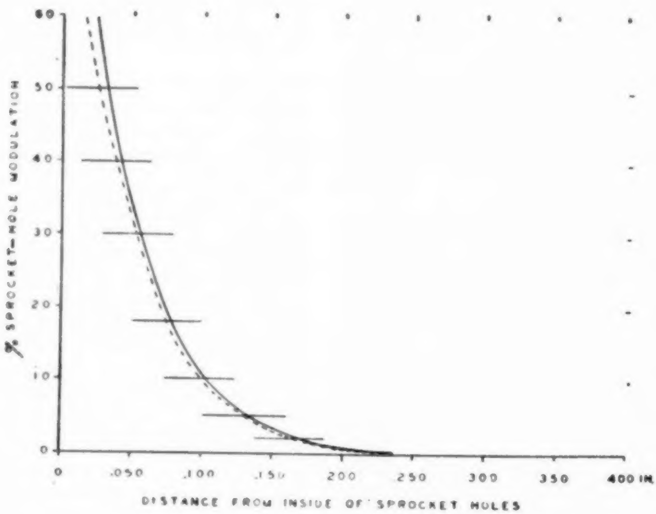


Fig. 2. Record-reproduce 0.050-in. head with 0.200-in. land.

Figure 2 is a plot of the distance of the record-reproduce head from the inside of the sprocket holes vs. the per cent sprocket-hole modulation, using the 50-mil head with a land so as to simulate the contact of a 250-mil head. In this case the slit is toward the sprocket holes and the land is toward the center of the film. On the chart the placement of the slit is shown as a horizontal straight line and the vertical position of the line indicates the per cent modulation for each slit position. A solid line is drawn through the center of the respective slits and a dashed line to the left of the solid line crosses the slits at the point where the per cent sprocket-hole modulation for a small increment of the slit length equals the per cent modulation for the entire slit. The dashed line, therefore, indicates the per cent sprocket-hole modulation actually existent at any distance from the inside of the sprocket holes.

As indicated by the dashed line, the sprocket-hole modulation is 5% at 130 mils from the inside edge of the sprocket holes, 10% at 100 mils, 18% at 75 mils and 32% at 50 mils. In other words, that portion of the film between 100 mils and 50 mils contributes 10% to 32% sprocket-hole modulation. This area is within the scanned area of the proposed ASA standard.

Figure 3 is a plot for a 250-mil record-reproduce head. This shows how the bad sprocket-hole modulation close to the sprocket holes is masked and subdued by the good reproduction far removed from the sprockets. If a 250-mil sound track width is used, starting 50 mils from the sprocket holes, the sprocket-hole modulation will be 3.5% or 4% and the quality will be impaired but marginal. If the 250-mil sound track starts 100 mils from the sprocket holes, the sprocket-hole modulation will be approximately 0.5%.

Figure 4 shows the per cent sprocket-hole modulation for a 50-mil (A), a 150-mil (B), a 200-mil (C) and 250-mil (D) slit, each starting 100 mils from the sprocket holes. Similar information is shown at E, F, G and H for slits starting 50 mils from the sprocket holes. Line G represents the present proposed ASA standard (a 200-mil record-reproduce head starting 50 mils from the sprocket holes) which averages 5.6% sprocket-hole modulation. Previous measurements made by others and submitted to the Motion Picture Research Council indicate a sprocket-hole modulation of 4.5% for this condition.

Line B shows that a 150-mil head starting at 100 mils from the sprocket holes and extending to the same inside line as the proposed ASA standard (right-hand end of both lines G and B), will reduce the sprocket-hole modulation from 5.6% to 2%. The loss in level is approximately 2.5 db.

For both 35mm and 17½mm recording the writers recommend the sound track placement shown in Fig. 5A. Fortunately, this placement also meets the editorial requirements which are set forth in the second part of this memorandum. It is further recommended that heads be aligned so that the end of the slit shall be 131 mils from the inside edge of the sprocket holes and that this condition shall prevail regardless of the length of the slit in the head. Referring to Fig. 2, this 131 mils is the point at which the incremental measurement is 5% and any further encroachment toward the sprocket holes is undesirable.

In this recommendation the sound track is 200 mils wide; however, any width head can be used and the recordings played on any width head as long as the alignment is as outlined above. Paramount has many 250-mil heads which will remain in service.

It is to be noted that recordings made on the ASA proposed standard will reproduce better under the conditions of this recommended procedure than on the ASA proposed standard. Further, recordings made on the basis of this

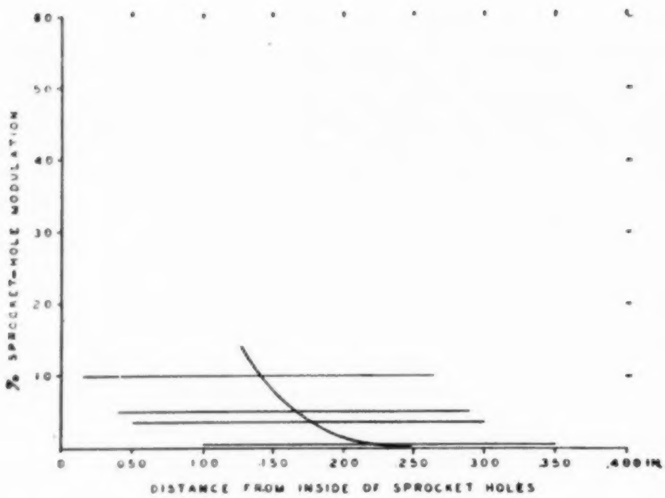


Fig. 3. Record-reproduce 0.250-in. head.

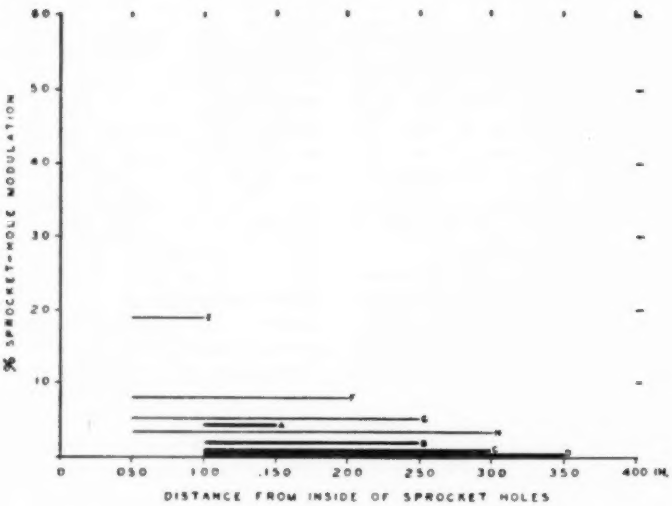


Fig. 4. Comparative sprocket-hole modulation — slits starting 50 mils vs. slits starting 100 mils from sprocket holes.

100 mils	*50 mils*
A, 50-mil head	E, 50-mil head
B, 150-mil head	F, 150-mil head
C, 200-mil head	G, 200-mil head
D, 250-mil head	H, 250-mil head

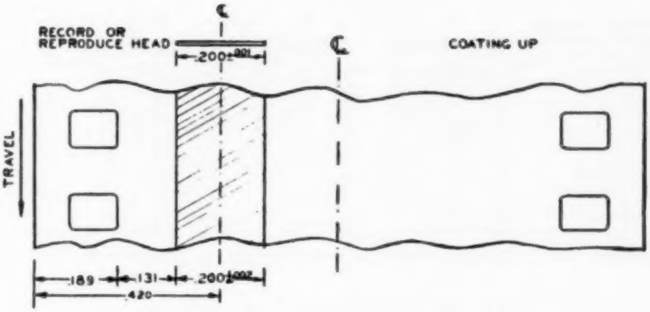


Fig. 5A. Recommended sound track placement.

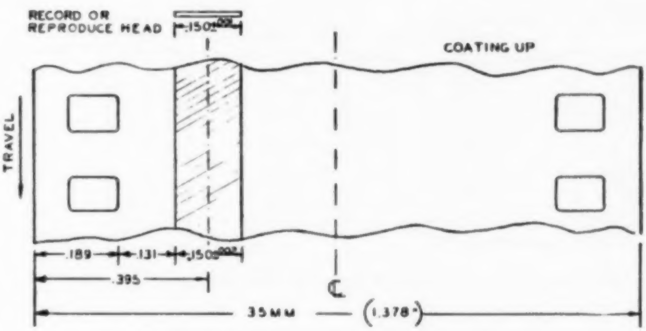


Fig. 5B. Alternate sound track placement for 150-mil head.

recommended procedure will reproduce better on the ASA proposed standard than a recording made and reproduced on the ASA proposed standard. In other words, whenever the work and/or equipment used is intermingled between old and new, the result is always improvement and never degradation.

If existing equipment is to be modified and if the 200-mil head cannot be moved to the position specified in Fig. 5A, most of the improvement can be gained by using a 150-mil head as shown in Fig. 5B.

It is expected that all three-track recordings will be done on full-coated magnetic film, although the future may show a preference for striped film having a clear area between each stripe. For three-track recording the writers recommend the sound track placement shown in Fig. 6A. If greater track-to-track isolation is desired, the placement (Fig. 6B) can be used. Either of these proposals will have less sprocket-hole modulation and less distortion than the ASA proposed standard.

As indicated earlier in this memorandum, the tests were made with full-coated magnetic film on equipment having the head in the drum. This is the basis on which the original standardization was contemplated and is the condition of most magnetic recording. Tests which have been made show a slight preference in favor of magnetic film that is not coated in the sprocket-hole area and also there seems to be some

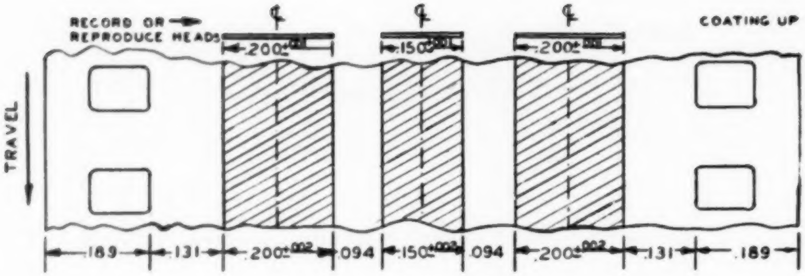


Fig. 6A. Three-track recommendation.

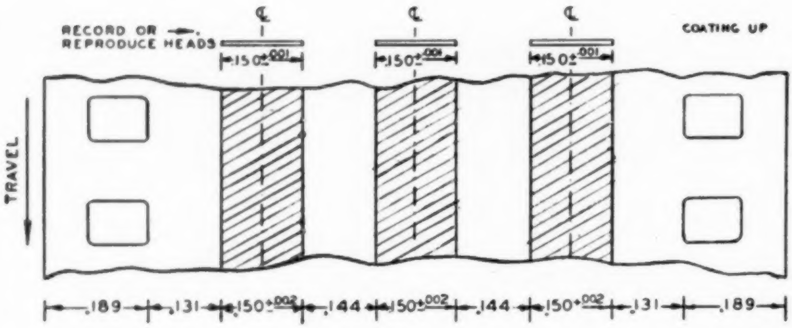


Fig. 6B. Alternate for three tracks.

improvement with recorders of the two-flywheel type. However, as most of the equipment and most of the magnetic film used are the type used in this test, the standard should meet these requirements. Listening tests made subsequent to the above measurements indicate that under certain conditions of single-drum handling of 17½mm magnetic film, sprocket-hole modulation is greater than with 35mm magnetic film. As far as the writers know, no measurement studies have been made of this effect, even though over half of the production recording is on 17½mm magnetic film.

The tests reported in this paper were made by recording a 3072-cycle frequency on the film and observing the ratio of peak amplitude of 96-cycle to 3072-cycle reproduction on an oscilloscope. Previous measurements made with the harmonic wave analyzer also included film irregularities and were found to be misleading at these relatively low percentages. Intermodulation analyzers include the other film irregularities in their measurement and are, therefore, not indicative of 96-cycle, sprocket-hole modulation. The percentage of 96-cycle modulation is almost independent of signal amplitude.

In general, the sprocket-hole modulation described above has gone unnoticed and has caused little trouble in recording. This is because most companies are still working with only first copy transfers or intermediate film procedures. These modulation effects will become more obvious when film

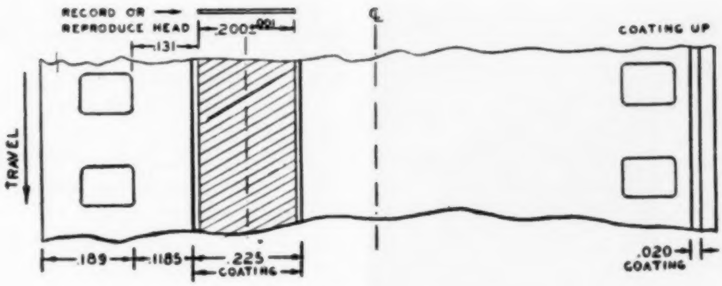


Fig. 7A. 35mm magnastripe.

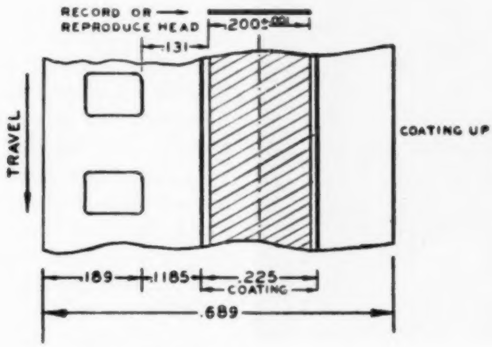


Fig. 7B. 17½mm magnastripe.

losses are eliminated from the procedure and when the number of generations is increased. The reason why many people prefer ¼-in. tape as compared to sprocket-driven magnetic film is because of sprocket-hole modulation. We should not accept a standard that limits future development, especially when a better standard is available without increased cost and without damage to the recordings already made.

Editorial Handling

Sprocket-driven magnetic film may be assembled and handled in simple editing much the same as ¼-in. magnetic tape. However, most motion picture editing involves so much overlapping, modulation matching and selecting of the best place to cut that a more positive system seems desirable.

Experience at the Paramount West Coast Studio and Ryder Services indicates that some form of visual modulation is essential to convenient cutting of magnetic film. The initial work with modulation writing* on the magnetic coating was a step in the right direction; however, it required front viewing of the modulation writing, whereas editors are equipped for and are in the habit of viewing both picture and sound by transparency.

After checking all combinations of sound track placement and every known

* L. L. Ryder, "Motion picture studio use of magnetic recording," *Jour. SMPTE, 55:* 605–612, Dec. 1950.

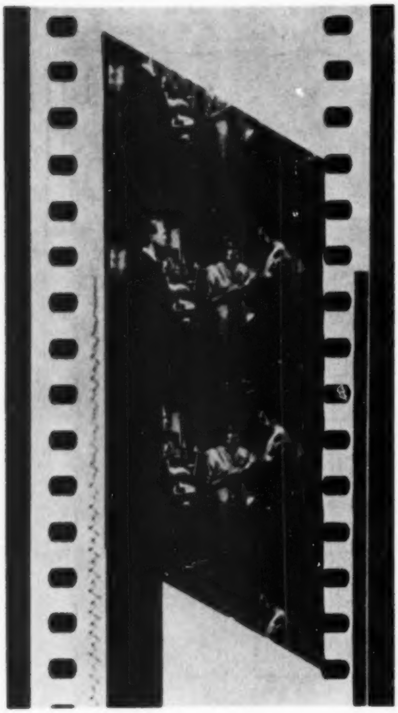


Fig. 8. Magnastripe film placed on top of picture film for synchronous handling.

form of modulation writing, Paramount and Ryder Services have selected the striped magnetic film shown in Fig. 7A for 35mm editorial work. This has a stripe of magnetic coating 225 mils wide with center line 420 mils from the edge of the film. A 20-mil stripe is placed near the sprocket holes on the side of the film opposite the sound track so as to balance the roll for winding. Figure 7B shows a coating of magnetic film for $17\frac{1}{2}$mm use. In manufacture two stripes of magnetic coating are placed on 35mm film and later slit to give two $17\frac{1}{2}$mm films.

For both 35mm and $17\frac{1}{2}$mm editing, the modulation writing is placed on the film in the clear area between the striping and the sprocket holes. An illustration of the 35mm film along with picture is shown in Fig. 8.

By reviewing Fig. 8 it will be noted that:

1. When the picture and sound films are placed on top of each other, the modulation can be seen by transparency through the clear area of the picture. This procedure is a common editorial practice with optical sound film.

2. The picture can be seen by transparency through the clear area of the sound film. The area available for viewing is the same as under the present practice with 200-mil, push-pull optical recording.

3. The code numbering used for synchronization can be viewed in transparency and matched.

4. The picture and sound film still held together can be run through a picture-only or sound-only magnetic Moviola unit.

5. Markings can be made on the film in crayon or ink and read in transparency as at present. Crayon markings should not be made in the sound track area.

6. These films can be handled in regular existing editorial equipment including synchronous rewinds. The only conversion necessary is the magnetic reproducer on the Moviola and a magnetic reproducer or conversion for the review room.

7. These films can be handled by the existing editorial techniques which have

been evolved after many years' practice and experience.

8. The magnetic cutting print is also used as the dubbing print.

9. The modulation writing is on the base side of the film and can be removed with carbon tetrachloride.

10. The film can be erased, cleaned and re-used many times.

11. The magnetic sound track placement leaves the photographic sound area clear. This makes it possible to intercut magnetic and photographic sound films.

12. It is also possible to stripe photosensitive film either before or after processing. Under this proposal it will, therefore, be possible to have both photographic and magnetic sound on the same piece of film. This may be of great value in newsreel work, narration recording and editorial processes, including scoring and dubbing.

13. For most reproducers these films can be spliced on hot-lap splicers if the blades are demagnetized.

Many combinations of sound track and modulation writing position have been tried and abandoned. There may be a slight advantage in favor of having the sound track in the so-called positive position instead of the so-called negative position. This would involve so many changes in equipment that it is not recommended. In these considerations we have also reviewed the question of under- vs. over-scanning of striped magnetic film. Practice to date indicates that there is no preference.

General

Fortunately the best-known specification for editing is the correct specification in regard to sprocket modulation.

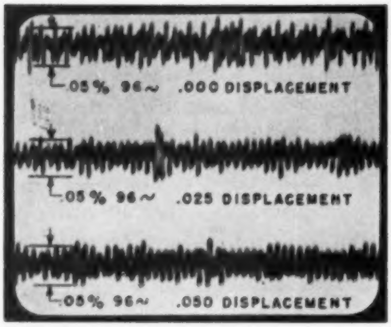
Paramount West Coast Studio and Ryder Services, along with a goodly number of the recording companies, have from the inception of magnetic recording used a sound track placement such that the center line of the sound track is halfway between the inside of the sprocket holes and the center of the 35mm film. We are abandoning these specifications in favor of the new suggested procedure. We hope that others in the industry will take advantage of our work. We have no hesitation in taking this step because, as stated earlier, films can be interchanged and any film that is either recorded or reproduced in accordance with this suggestion will play better than a film that is both recorded and reproduced under conditions of the ASA proposed standard.

We urge that the Society of Motion Picture and Television Engineers and the Motion Picture Research Council reject the present proposed ASA standard and along with other possibilities consider the suggested procedure set forth above.

Discussion

J. L. Pettus: It appears that the experiences by us at RCA do not quite agree with Mr. Ryder's. In fact, some of our data might take exception by as much as ten to one. With your permission, I would like to illustrate a point or two by the use of a few slides. These slides consist of measurements of 96-cycle flutter as well as amplitude modulation and I would like to present them in view of the statement Mr. Ryder made that his method of evaluation was (1) by listening and (2) by measuring, and in view of the method by which he measured. Possibly we take exception to the method of measuring.

At the top of Slide 1 is an oscillogram of 96-cycle flutter measured from a



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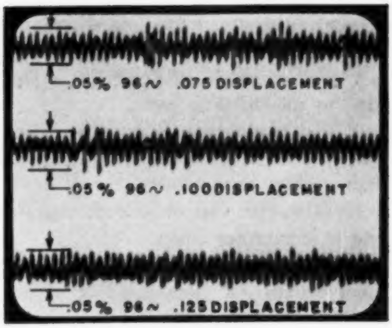

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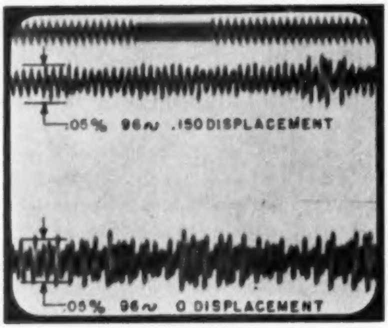
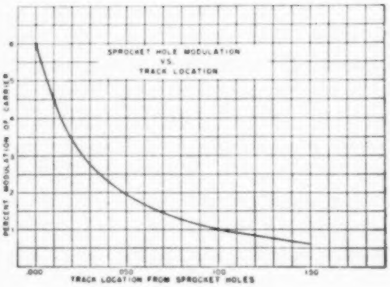


Slide 3.



Slide 4.

3000-cycle tone recording where the magnetic track was laid down at a 0 displacement from the sprocket hole. In other words, the edge of the track was directly adjacent to the perforations. The second oscillogram was made with the head moved over 25 mils. You will note in the first, that the average value of 96-cycle flutter is somewhat greater than 0.05% and when the head is moved over 25 mils, the average value drops a little less than 0.05%. In the third oscillogram, the head was moved over 50 mils and the same amount of 96 cycles seems to prevail. Slides 2 and 3 show a continuation of flutter measurements where the head was moved in increments of 25 mils and measurements were taken at 50-, 75-, 125- and 150-mil displacement. Again, the amount of 96-cycle flutter shows little or no change over that shown in the second oscillogram where the head is just removed from the perforations. Slide 4 deals with the measurement of amplitude modulation as indicated on an intermodulation set reading only the amplitude variations. Here we notice that the top of our curve shows a value of 6% modulation of the carrier and may be compared to that in Mr. Ryder's illustration which, I believe was approximately 60%. Our measurement at this point was taken when the track had a 0 displacement from the perforations. Now, if we move over 25 mils, we find 3.5% modulation followed by 2% at the 50-mil displacement and

1% at the 100-mil displacement. It is seen that the curve flattens out rather quickly. If the signal is raised in frequency to, say, 7000 cycles, this entire curve moves slightly toward the perforation base line and also increases its height. Judging from these data, we see no real gain in changing the proposed standards, but instead, we see several complications arising in the use of triple tracks and at the moment I have not seen Mr. Ryder's proposal on how he would arrange three tracks along the 35-mm film in satisfactory manner.

Dr. J. G. Frayne: I think Mr. Ryder's figure of 60% was based on a 50-mil track rather than a 200-mil track that Mr. Pettus's figures were based on. Is that right?

Mr. Pettus: That is correct. Those tests were made on standard 200-mil track.

L. L. Ryder: Please refer to the Slide 4 which was presented by Mr. Pettus. The graph line indicates the percentage of sprocket-hole modulation for different positions of head placement with respect to the sprocket holes. At a position of the head such that the end of the slit is 50 mils from the sprocket holes, the sprocket-hole modulation is shown as 2%. Now, please refer to Fig. 3 in my paper. This happens to be for a 250-mil head and the reading of sprocket-hole modulation is approximately 3.5%. The data, therefore, are not out of agreement by a ratio of 10 to 1, as indicated by Mr. Pettus, but by a ratio of 3.5 to 2, which is 1.7 to 1.

Now, referring to Fig. 2 in my paper, it is to be noted that at 50 mils from the sprocket holes the incremental sprocket-hole modulation is 32%. If this is to be reduced by the factor of 3.5 to 2 to conform with the RCA data, the amount of sprocket-hole modulation introduced would be 18%. It is my feeling that we should not introduce 18% sprocket-hole modulation in order to meet a proposed standard.

The validity of our measurements has been questioned. We believe our measurements to be correct, but in any case our measurements have been related to what can be heard, and what we can hear is the thing about which I am most concerned. Our first observations of this phenomena were the result of listening tests made with the proposed ASA standard. Both the RCA data and the data prepared by the writer indicate that a change should be made.

F. R. Wilson, Vice-chairman of the Session, read a communication from L. D. Grignon, Twentieth Century-Fox Film Corp., reporting data from an investigation of 96-cycle modulation made recently on regular production equipment:

"Recordings were made on a Westrex RA-1231 recorder modified for magnetic recording, using a 250-mil track with the nearest edge 50 mils from the sprocket hole. This recorder uses a compliant mounted head adjusted to 90-g pressure and a special recording drum which supports as much of the film as possible. A signal frequency of approximately 3000 cycles was used at a level which produces 1% harmonic distortion. During reproduction the output was observed on an oscilloscope by the same method as reported by Ryder and Denney, the exact signal and sweep frequencies being adjusted to give the most readable traces. Since the peak-to-peak 96-cycle modulation is of the order of 3%, the reading error was considerable due principally to random amplitude fluctuations and noise; therefore, readings of total peak modulation distortion products were made by the use of an Altec TI 402 intermodulation analyzer. Two film stocks were used with the results shown in Table I. When the 96-cycle modulation is less than 2.5%, the oscilloscope reading accuracy becomes seriously questionable and, therefore, in some instances data are recorded only for the intermodulation analyzer measurement.

Table I.

Recorder	Reproducer	Oscillo-scope % 96-cycle peak modulation	Intermod. analyzer % total (peak)	Notes	
RA 1231	RA 1231	3.3	4.0	Roll 9601	Old film
RA 1231	RA 1251	2.5	3.5	Roll 9601	Old film
RA 1231	RA 1231	—	1.2	Roll 1336	New film
RA 1231	RA 1251	—	1.2	Roll 1336	New film
RA 1251 (3-track)	RA 1251 (3-track)	—	1.2	Roll 1336	Track 1 (outside)
RA 1251 (3-track)	RA 1251 (3-track)	—	1.7	Roll 1336	Track 2 (center)
RA 1251 (3-track)	RA 1251 (3-track)	—	1.0	Roll 1336	Track 3 (inside)

Table II. Recorded on RA 1231 and Reproduced on RA 1251.

Magnetic film roll no.	Date first used	Approx. no. of times used on prod.	Oscillo-scope % 96-cycle peak modulation	Intermod. analyzer % total (peak)	Remarks
9596	12-31-49	10	2.0	1.9	Many random variations
9915	2-2-50	12	1.80	1.8	
0607	4-1-50	7	2.60	2.6	
1415	5-19-50	9	2.10	2.0	Many random variations
1563	5-22-50	9	1.75	2.2	
755	10-17-50	5	2.20	1.9	
6650	11-29-50	6	1.75	1.7	
925	3-8-51	5	1.25	1.4	
1010	3-26-51	3	1.5	1.5	
1298	9-7-51	1	2.0	1.7	

"The considerable differences between the two stocks prompted another series of measurements of the same kind on a variety of stocks. These results are shown in Table II with pertinent historical data concerning each roll. From Table II it may be concluded that: (1) with the recording and reproducing equipment used at the subject studio and the magnetic film stocks currently in use, the maximum total amplitude distortion products do not exceed 2.6% (Note — Roll 9601 of Table I is used only for preliminary maintenance tests); (2) there has been some improvement during the past $1\frac{1}{2}$ years, due either to reduced random amplitude irregularities or improved perforations; and (3) there is little correlation between usage and amplitude distortion products.

"It can be expected that the amplitude distortion products due to 96-cycle modulation will increase in some fashion when multiple generation recordings are made from a given piece of material, but this is also true of all other amplitude irregularities, noise and flutter. The number of good-quality generation records which can be made is determined

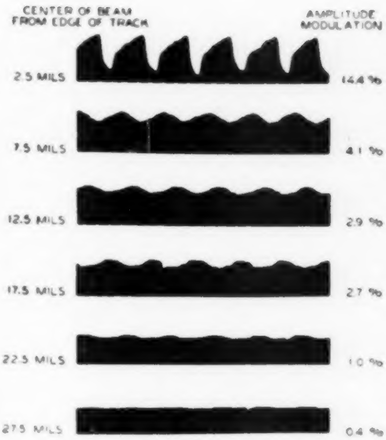
by all these factors, not by 96-cycle modulation alone.

"Considering the data and the particular equipment in use at Twentieth Century-Fox, it appears that a change in track position to some location other than the standard now proposed by the Society would be of very questionable merit. It would seem that the greatest benefit can be obtained by film improvement, particularly with respect to uniformity of high-quality perforation and low-valued random amplitude irregularities."

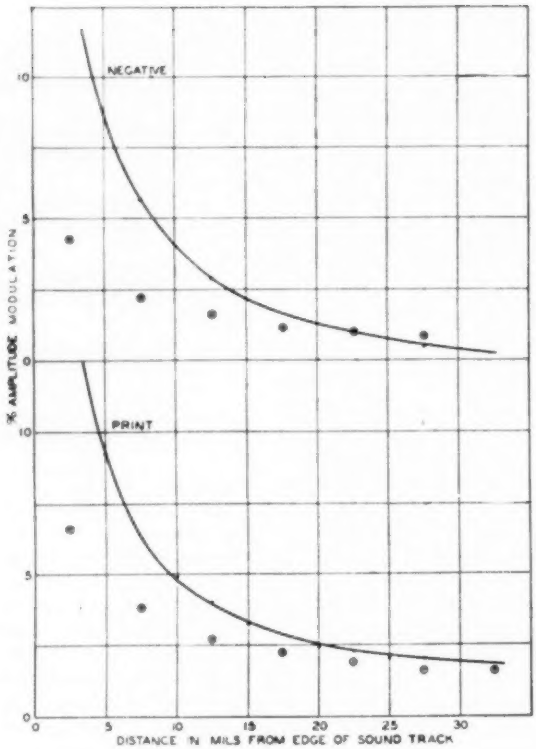
Mr. Ryder: As an operator and as a director of sound activity in the making of motion pictures, it is not my good work that causes me trouble but my bad work. I am, of course, very concerned about test data. I do want the data to be correct and accurate, but with respect to what I put in my plant, and I should think this would apply to others, I want first of all that it cause me no trouble. The Fox data show 3.5% to 4% sprocket-hole modulation on old film. These data correspond almost exactly to the data shown in Fig. 3 in my paper, which in turn indicates to the writer that an incremental measurement on the Fox equipment would correspond to Fig. 2. I should, therefore, expect Fox to be able to hear the same sprocket-hole modulation that we are able to hear at Paramount.

It is my belief that all users of magnetic recording contemplate the re-use of film, which means the use of old magnetic film. In the taking of our data we found variations and inconsistencies between batches of magnetic film. The sprocket-hole modulation of old films is generally higher than that of new film. These are the films that can cause trouble and this is the trouble that can be avoided by changing the proposed standard.

Dr. Frayne: It is interesting that information presented by Mr. Pettus was made on films using a double-flywheel-type drive, whereas Mr. Grignon's information was obtained on a recorder using the single-drum-type drive with the head located at the drum. So we have two different philosophies of film drive and the results are more or less comparable. Therefore, what is wrong with Mr. Ryder's data? First of all, 96-cycle sprocket-hole modulation is nothing new and is not confined to magnetic film. I wrote a paper on this subject in 1935 and if we may have the first slide (Slide 5 in this printed version) I can show you some of the things we found on a typical negative photographic sound track. This was done not with a 50-mil head, but rather with a 5-mil head. At 2.5 mils from the sprocket holes (in other words, the center of the 5-mil head was 2.5 mils from the edges of the sprocket holes), we got severe amplitude distortion on a 3000-cycle track. At 7.5 mils the amplitude modulation was a little better, at 12.5 mils a little better yet, and at 27.5 mils it had just about disappeared. I'm not claiming that the amount of sprocket-hole modulation you get in photographic is identical in amplitude to what you get on magnetic due to the greater depth of focus on photographic, but on the other hand the trend is there showing



Slide 5.



Slide 6.

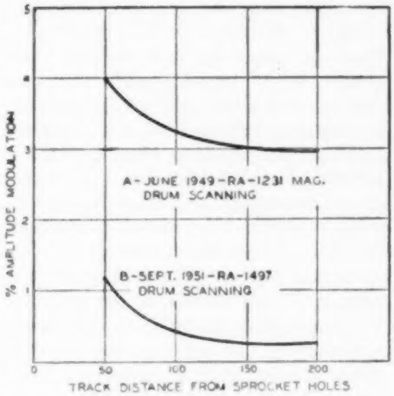
how it varies as it moves in from the sprocket-hole edge. Photographic recording is all recorded on a drum and reproduced at a drum; therefore, the conditions as far as polygoning are concerned are the same. This effect shown here was not due to any laboratory effect. The negative track described above and the resulting print were developed in a special tank which eliminated any laboratory development sprocket-hole modulation.

Slide 6 shows plots of results. There are two methods of measurement. The heavy solid curves were taken on a microphotometer, which took in all the peaks. The dotted points are the measurements made with a device which is quite similar to the modern intermodulation analyzer. And you will notice, disregarding the amplitude because it shouldn't necessarily be the same in photographic as magnetic, that the effect flattens off pretty much around 25 or 30 mils. Based on this information we set up, in cooperation with MGM, the 200-mil push-pull track in the so-called offset track position. Now the intermodulation analyzer, when used to measure amplitude modulation, measures not only 96, it also measures everything else. The statement, made in Mr. Grignon's contribution above, that they got 4% on old film was used by Mr. Ryder as favoring his case; but it doesn't favor his case at all because

there is no reason at all why 96 cycles should be affected by old film. The old film is contributing the hash, the 96 is very much the same. I see no reason why the 96-cycle should change appreciably. If you're going to use old film, you're going to get more amplitude modulation of a general nature.

Dr. Wolfe and I set the track position at 135 mils which incidentally is what Mr. Ryder is proposing now. We found that it was a very good position to operate in because sprocket-hole modulation was at a minimum. And we would have been very happy to stay at 135 mils, if we hadn't had this kaleidoscopic Hollywood, this ever-changing situation to contend with. We no sooner got it set there when up came John Livadary with his bright idea of three tracks on 35mm film. As a result, RCA and ourselves got together to study where we could put these tracks. Westrex thought that 75 mils in from the sprocket-hole edge would be a good compromise. At first nobody worried much about the crosstalk between adjacent tracks. But when it was decided to use these tracks for storage of three independent films the situation began to get fussier as to crosstalk, and as a result we had to work out a wider separation of the tracks, resulting in the outer tracks being located 50 mils in from the sprocket holes.

At that time, in 1949, we measured amplitude modulation products and the information was presented orally to the Research Council. I would like now to show a slide (No. 7) which will show the measurements we made in July 1949 on amplitude modulation with the film as it was in those days. The upper curve was made on the RA-1231 Magnetic Recorder drum and at 50 mils in it shows 4%, but it dropped very little until we went in as far as 200 mils. It never dropped much below 3%. In other words, it looked like it would never get below 3% no matter where you located the track. The only conclusion I could draw from that was that the



Slide 7.

residual amplitude modulations undoubtedly came from scratches and dirt and hash. Now since Mr. Ryder made his proposal to change the proposed standard we repeated the measurements in September 1951. This time we used our new RA-1497 Recorder with drum scanning. There are some significant differences. The drum size is greater on the 1497 than it is on the 1231 and we know from previous studies that sprocket-hole modulation is generally more severe with small drums. It's also a matter of film tension. In the case of magnetic recording it is also a function of the tilt of the head. We obtained the lower curve shown in Slide 7. You will notice that at 50 mils in we get slightly over 1% which agrees with Mr. Grignon's contribution.

Mr. Ryder has said that amplitude modulation experts could hear 2%, halfway experts 5% and the public 10%. There are no published data, although the Bell Labs did some work on this problem, on how much amplitude modulation a person can hear. First of all, it depends on many factors, the frequency that is being modulated, whether it's 100 cycles, 1000 or 10,000. It also depends on the modulation rate, just as flutter does. I tried to work out

something that might help us see what would be the minimum we could hear. With an amplitude modulation of a carrier only two sidebands are produced. If you have, say, 20% amplitude modulation, 10% lies in each sideband. In flutter, on the other hand, which is an FM type of modulation, one obtains an infinite series of sidebands, that is, if the modulation index is high enough. When the modulation index is low enough in FM you also get only two sidebands. So it's natural to suppose that a flutter having this index of modulation would sound to the ears just like an amplitude modulation having the same sidebands. Now, the maximum value of the modulation index at which you can neglect the higher orders of sidebands in FM is of the order of 0.025, the first-order sidebands being about 10% of the carrier. This index of modulation is designated by the Greek letter α.

Now,

$$\alpha = \frac{\Delta f_0}{f_m}$$

where

Δf_0 = frequency deviation of the carrier

and

f_m = the modulation (i.e., flutter) rate.

Substituting:

$$\alpha = 0.025 \text{ and } f_m = 96,$$

$$\Delta f_0 = 2.4 \text{ cycles}$$

The flutter in a 3000-cycle tone is given in % by:

$$\text{flutter} = \frac{2.4 \times 100}{3000} = 0.08\%$$

We noted previously that for this flutter condition the first sidebands were 10% of the carrier. In the case of amplitude modulation, this corresponds to a value of 20% since one-half, or 10%, lies in each sideband. Similarly, a 10% amplitude modulation corresponds to a peak value flutter of 0.04% at the 3000-cycle rate. Now, this is about as good a commercial film reproducer as can be built and it would seem to signify that 10% amplitude modulation would be largely inaudible, at least at 3000 cycles.

What minimum 96-cycle flutter can be detected is somewhat controversial. It depends on the person and it depends on the room in which the tone is being heard. Manufacturers of sound-recording equipment have tried to keep 96-cycle flutter somewhere between 0.05% and 0.1% and we think 0.05% is pretty good. It would appear, therefore, that we could similarly tolerate 10% amplitude modulation. Since our graphs show a little over 1% in new film, we do not feel that there is any great problem in the proposed location of the track.

Mr. Ryder: With respect to the optical versus magnetic comparison of sprocket-hole modulation, it should be noted that with optical film as long as there is a signal across the film, it is seen by the photoelectric cell. Sprocket-hole modulation on optical film is the result of a change in photosensitivity due to punching, a change in the developing effect near the sprocket holes due to agitation, and polygoning. In magnetic recording and reproduction the effect that we are noting is a result, partly at least, of deformation from punching which causes a fluctuation in magnetic head contact with the film. All one has to do is hold the film in reflected light and observe the deformation from punching.

There is another phenomenon that has been observed — that the effect of sprocket-hole modulation varies with frequency. We have not searched for the point where the highest modulation takes place. We should expect the modulation effects to be greater at higher frequencies and lower in the 2000-cycle range where the more recent Westrex tests were made.

With respect to the old films, our definition of old film as presented here a few minutes ago is not so much a

question of age in time as a question of age in usage. By examining film that has been used many times, the sprocket wear and deformation are quite obvious, which can only increase rather than diminish the problem. At Paramount and at Ryder Services, where we are using the sound track placement suggested here, we use old films interchangeably with new films and have noticed no bad effect. We see no reason for buying new film because of any deterioration of the film or from the standpoint of the hash mentioned by Dr. Frayne.

I do not have data to show the effect of increase or decrease in this hash. I should point out, however, that the system of measurement used by Paramount separates sprocket-hole modulation from the so-called hash; whereas all of the other data presented at this meeting combine sprocket-hole modulation and so-called hash to the point of confusion. As pointed out in my paper, Paramount changed from the distortion and intermodulation type of measurement to the use of the oscilloscope in order to avoid this measurement trouble.

I should expect that in the future we might develop recording machines and magnetic film which will have less sprocket-hole modulation than we are now encountering. We have presented this paper on the basis of a recorder under normal present-day conditions of operation. If we were to repeat these measurements as we have in the past on several occasions, our results would be the same.

I concur with the mathematics which Dr. Frayne has placed on the blackboard. I was careful and punctuated my wording with respect to our observations of percentage modulation and made it clear that these observations were under our conditions of use and measurement. Our first concern is what we can hear, what can be heard by the average person and what annoys the average person. Our measurement data are related to these observations. It is my feeling that any measurements and any data which are tied into flutter modulation may be quite different from that which is now taking place with respect to amplitude modulation. Many people are confusing these two types of modulation. We were confused at first, but it is quite clear to us now that our concern is amplitude modulation which, incidentally, can be additive along with generations of transfer. When each generation of transfer adds up in the same direction, you can gain a very high percentage of sprocket-hole modulation. Unfortunately, they never completely cancel. Again I say, it is the occasional bad quality and not the good quality that causes us trouble. We are endeavoring to eliminate the occasional bad quality. We hope that this elimination will also improve the good quality.

We present this information to the Society of Motion Picture and Television Engineers and the Research Council as a study which we have made in all sincerity with the thought that the knowledge that we have gained should be made available to all. The utilization of this knowledge, its acceptance or its rejection, is up to the Society and the Research Council.

I should clarify one point and that is I doubt if Paramount will move over to 50 mils from the sprocket holes. In any case, Paramount will make its recordings and reproducers so that they can be played interchangeably with whatever standard is finally accepted. I am very much opposed to getting into another turmoil of the type that now exists on 16mm work.

Mr. Mueller: I think it is time that you should hear from the Sound Committee of the Research Council who drew up these present standards and who presented them to the SMPTE. These proposed standards were published in July of 1951.

You have heard the pros and cons as presented here which is really an extension of the discussion in our committee, as most of the information shown today was gathered at the request of our committee and discussed thoroughly at meetings extending over more than two years. We finally decided that it was very important to all of us that no more delays be tolerated and that the magnetic standards favored by the vast majority of the committee be adopted.

Speaking as a member of the Sound Committee of the Research Council and as its present chairman, I want to state that we propose to stand by the standards as established and as published.

There have been 150 channels built by the two major manufacturers here in Hollywood based on the performance given in the slides presented here today; and as far as I know, Loren, you have the only machine that does not work. So I think that rather than move the standards, perhaps you should fix your machine.

Mr. Ryder: I wish to make a point clear for the record; and that is, if the Committee of the Research Council have made up their minds before they hear an honest debate of this discussion, I don't think it's worth while to follow the recommendation of the Research Council. I don't believe that it is on that basis.

Mr. Mueller: I have recently discussed this with the other members of our committee, of which you are a member, and we see no reason for changing our opinions which were based on a study of more than two years.

L. T. Goldsmith: As Chairman of the Sound Committee of the Society, I wish to reconfirm that our Subcommittee on Magnetic Recording, under the chairmanship of Glenn Dimmick, had given wide study to all the proposed standards on magnetic sound track for over three years before they were published in the July issue of the Journal. Any comments received during the 90-day trial publication period are welcome and will be carefully studied by the Subcommittee. I would like to point out, however, that in the interest of avoiding industry chaos it is to the best interests of both the users and manufacturers of magnetic-recording equipment that standards which are used and approved by the great majority be adopted as rapidly as possible.

Added note by Mr. Ryder: Although it was not discussed at the meeting, the data collected at Paramount have been questioned on the basis that some of the measurements involve a larger-than-normal space between the drum and the record-reproduce head. We have curves to show that very bad effects can be produced by improper adjustment and tension of the head, especially under such conditions. The data presented and the curves shown in the paper are for the conditions where these effects would not exist and further, the curves as presented, and as shown by the graphs, tie together with measurements made with heads located as recommended by the manufacturers.

New Principle for Electronic Volume Compression

By HAROLD E. HAYNES

The principle described is a radical departure from those heretofore used in compressors. The features of this compressor are extremely low thump, very fast action (if desired), low distortion and freedom from the need for special circuit components or selected tubes. Fundamental circuits are discussed, and performance obtained with a complete compressor embodying the system is presented.

A VOLUME COMPRESSOR is an automatically actuated variable-gain amplifier, used for reducing the dynamic range of program material. The timing characteristics of the voltage derived from the signal for actuating the variable-gain amplifier are customarily such as to provide a very rapid gain reduction whenever the signal level rises abruptly, but to increase gain relatively slowly when the signal level drops. Very short acting times, less than one millisecond, are often used in order to minimize unwanted initial peak amplitudes on sounds having sudden large increases in envelope amplitude, such as certain spoken syllables.[1] If a change of gain is accompanied by a shift in d-c axis of the wave, a spurious aperiodic signal, commonly called "thump," will be produced. The d-c component of this shift will, of course, be filtered out by the low-frequency cutoff characteristic of the system; nevertheless, to the extent that the gain-reducing action can be considered instantaneous, this shift is a step-function and contains energy at all frequencies. The more rapid the attack and the better the low-frequency response of the system, the more objectionable will be the thump.

Presented on October 18, 1951, at the Society's Convention at Hollywood, Calif., by Kurt Singer for the author, Harold E. Haynes, Radio Corporation of America, RCA Victor Division, Bldg. 10-4, Camden 2, N.J.

Background

Brief mention of a few commonly used methods of varying gain will serve to point out their shortcomings as far as balance, or tendency to produce thump, is concerned. The most common type of compressor employs as a variable-gain device some nonlinear electrical element, an element in which the two electrical quantities employed as input and output are related by a curved characteristic. This type of element is utilized in such a way that the slope of the characteristic at the

operating point determines the gain of the circuit in which it is connected (which in general may be either greater or less than unity). Variations in gain are produced by superimposing upon the input signal an adjustable control signal, the amplitude of which determines the operating point. Examples of this type of variable-gain device are nonlinear semiconductors, such as Thyrite, and vacuum tubes as usually used in compressors and limiters.

In the latter class is the familiar "variable mu" or "exponential" pentode, in which various points on a curve of transconductance vs. grid voltage are selected by adding a control voltage to the signal in the grid circuit. It is clear that in this case, as with all others in which the control effect is merely a bias superimposed upon the signal, there will inevitably be an output component produced by a change in gain, and hence a thump.

There are other vacuum-tube variable-gain circuits in which the controlling voltage is not superimposed upon the signal. One example is the "loading-tube" circuit, in which the plate impedance of a tube is shunted across a relatively high-impedance signal source, and the value of this impedance is changed by varying the grid voltage. Here a family of curves of plate current vs. plate voltage exists, their slopes varying as a function of grid voltage. Unfortunately, however, changing from one curve to another causes a change in plate current, so that the same fundamental problem presents itself, as before. A generalization may be made to the effect that a change in any tube characteristic causes a change in plate current; hence, circuits of this class also suffer to a greater or lesser extent from an inherent tendency to thump.

The obvious and almost universal remedy is the use of push-pull circuits, in which signal is applied to the two variable-gain elements out of phase, while gain-control voltages are applied in phase. Recombining the outputs in push-pull fashion then makes the signal components in phase and the gain-control components out of phase, so that they tend to cancel. A great reduction in thump is thereby obtained, but it is apparent that in order for perfect cancellation to occur under all conditions the characteristic curves of the two elements must be identical at every point in their operating ranges. An estimate of the degree of similarity required if the thump level is to be negligibly low may be made on the basis of the following arbitrary but not ununreasonable assumptions: (1) that a change of gain between any two values within a range of at least 10 db should produce thump of the order of 40 db below signal level; and (2) that signal level is limited to 5% modulation of plate current by considerations of nonlinear distortion. These values lead to the conclusion that the plate currents must be equal (or differ by a constant amount) within something of the order of 0.05% throughout the operating range. Obtaining and maintaining the degree of similarity of characteristics necessary for such high-quality performance, though sometimes adequately accomplished, is expensive and time-consuming, and it frequently entails special selection and aging of tubes, plus frequent checking of those in service.

Principles of the New System

A means of varying gain by employing vacuum tubes, but one which is not based upon nonlinear characteristics, was thus sought and an approach which proved fruitful is described. It is based upon the principle of keying a transmission device between gain values of zero and some fixed value, at a high frequency, and obtaining different effective-gain values by controlling the relative durations of "off" and "on" periods. Otherwise expressed, this means amplitude modulating the signal with a high-frequency rectangular wave or

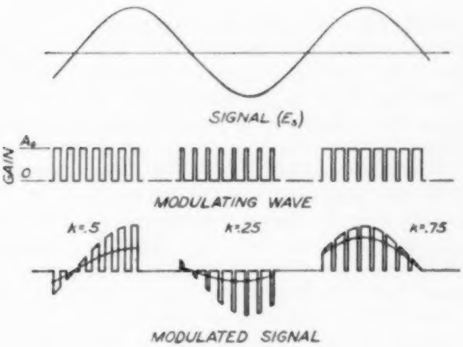


Fig. 1. Sinusoidal signal of frequency f_s modulated by a rectangular wave of frequency f_k.

series of rectangular pulses of varying duty factor. Of course, such a modulated signal contains high-frequency components not present in the original, but by proper choice of modulating frequency, these can readily be made inaudible and easily separable from the signal by filters.

The action is illustrated in Fig. 1. A sinusoidal signal of frequency f_s is shown modulated by a rectangular wave of frequency f_k, in which the duty factor is k. It is shown in Appendix A that the modulated wave contains the original signal multiplied by the factor k, plus an infinite number of modulation products of frequencies $nf_k \pm f_s$. It follows that if the maximum signal frequency component to be accommodated is, for example, 15 kc, the lowest sideband will be $f_k - 15$ kc. This sideband should be substantially higher than the maximum signal frequency, to facilitate removal of the sidebands. (It is pointed out later that the keying pulses should be as nearly rectangular as possible; hence, it is desirable to use the lowest permissible keying frequency, in order to minimize circuit difficulties.)

With the unwanted components of the modulated wave filtered out, there remains only the desired signal multiplied by k; hence, if the value of k can be varied in accordance with an appropriate control voltage, compression involving only linear electrical elements will have been accomplished.

Since the keying frequency must be at least 30 kc, a vacuum-tube circuit appears to be the only promising type of keying device. Hence, the same objection that was raised previously to tube circuits may at first seem valid, namely that a d-c component of plate current, which will change with changes in gain, will still be required. The important distinction here is that the tube will need to operate only *at one mean value of plate current* (corresponding to "on"), and *at cutoff* (corresponding to "off"). Thus, any two tubes can be used in push-pull, and substantially perfect balance can be obtained at their single operating points. They can, and should be, linear devices, and as such will permit relatively large signal amplitudes without objectionable distortion. Furthermore, their linearity may be enhanced by means of negative feedback, an expedient which would tend to nullify the gain-changing properties of conventional circuits.

Circuit Methods

Figure 2 shows the basic circuit of such a keyed amplifier. Two cathode followers are connected in push-pull, with positive keying pulses introduced in the cathode circuit. Pulse amplitude is sufficient to cut off plate current com-

pletely even when peak signal amplitude occurs. Additional positive bias voltages, E_{c1} and E_{c2}, permit desirable operating points to be selected, one of them being adjustable to permit balancing.

It is apparent that the keying pulses must have negligible rise and fall times, in order that the tubes will not be operating at points on their characteristic other than the desired one during an appreciable fraction of the time. This means that a minimum of capacitance loading should be permitted at any point in the pulse circuit. Therefore, resistors R_3 and R_4 are inserted to isolate the output transformer from the pulse circuit. Unwanted modulation products are removed by a simple low-pass filter following the out-put transformer.

An essential adjunct to the keyed amplifier, when used in a compressor, is a source of pulses of controllable duration and of approximately constant frequency, having the requisite relation between duration and control voltage. Appendix B shows that in a compressor deriving control voltage from output, as is customary, and having a slope of ½ on a decibel basis (2:1 compression), numerical gain should be inversely proportional to control voltage; hence, a pulse generator was developed in which the "on" (negative) pulse width closely approximates this relation. Figure 3 shows the basic circuit of the pulse generator. A 45-kc square wave, generated by a multivibrator, is differentiated by C_1 and R_5, to produce a series of alternate positive-voltage and negative-voltage pulses of very short duration. The negative pulses cause capacitor C_2, which is also connected to the grid of sharp cutoff pentode V_3, to be charged negatively once for each cycle, through diode V_2. C_2 discharges toward zero through R_6, which is connected to the source of control voltage, the latter being variable from zero to a relatively large positive value. Thus, the plate current of V_3 is cut off for a portion of each interval between pulses which becomes smaller as the value of the control voltage is increased. It is these periods of cutoff which eventually become "on" pulses for the keyed amplifier, their duration relative to the pulse period being the factor k. The time constant of C_2 and R_6 is made about equal to the pulse spacing (22 μsec), and the potential to which C_2 is charged by the negative pulses is about ten times the cutoff grid voltages of V_3; hence, V_3 draws no plate current unless the control voltage has a substantial positive value. This means that the significant part of the discharge curve of C_2 is reasonably linear, and it can be shown that this causes the duration of the cutoff period, and hence the value of k, to be nearly inversely proportional to the control voltage, as desired. The rapidity with which the value of k can be changed, and hence the speed of action of the compressor, in practice is limited only by the properties of the circuit by which gain-controlling voltage is derived.

The plate-current pulses of V_3, which are roughly rectangular because of its sharp cutoff characteristic, produce voltage pulses which are further shaped by subsequent amplifier and limiter stages so as to have very short rise and fall times, and applied to the amplifier circuit of Fig. 2.

These two basic circuits, with the addition of conventional means of deriving control voltage proportional to compressed output, and having the desired timing characteristics, constitute a complete compressor. Since this type of control circuit is well known, and for the present application need be little different from those for other compressors, this subject will not be discussed further.

Performance

A complete compressor based upon these circuits has been built and is

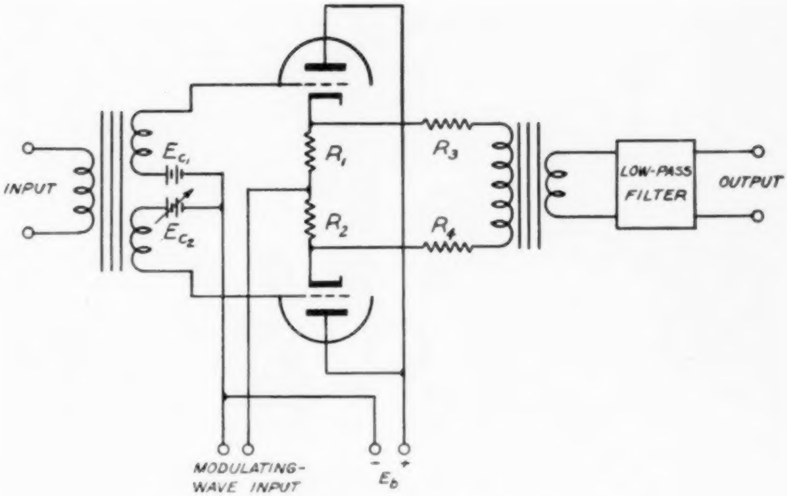


Fig. 2. Basic circuit of vacuum-tube keyed amplifier.

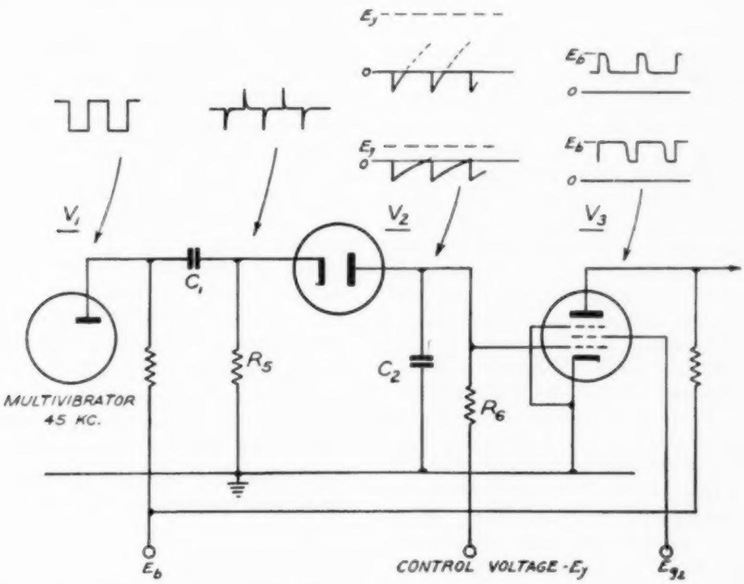


Fig. 3. Basic circuit of pulse generator.

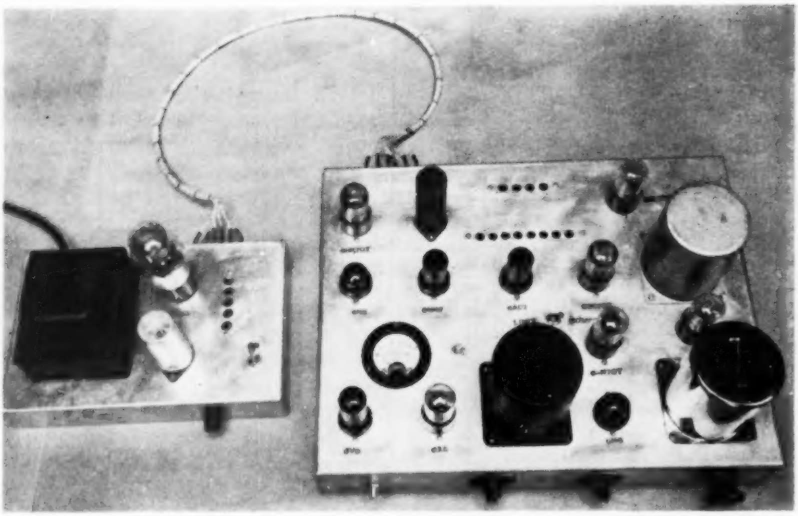


Fig. 4. Complete compressor based on the circuits shown in Figs. 2 and 3.

illustrated in Fig. 4. Its operating characteristics were made to conform to those of existing compressors so that its performance could be easily evaluated. Although this model is somewhat more complex than the simplest compressors, no special tubes or other special components are used. It affords a useful gain-reduction range of more than 15 db. Performance, especially with regard to thump, is excellent, both with respect to the degree of balance obtainable and to the long-time stability of this balance.

Two chief methods have been used for observing and measuring the effects of unbalance in compressors. One which is typical of actual operating conditions, described by Maxwell,[2] consists of abruptly raising the level of a relatively high frequency sine-wave input signal to the compressor and observing on an oscilloscope the transient appearing in the output. Although it depicts the thump phenomenon very graphically, this test is open to the objection that it takes into account balance conditions at only two specific points in the gain-reduction range. Also, in a well-balanced compressor the transient amplitude is too small to be conveniently observable. A second method, often built into compressors as a balance check, measures cross modulation between the gain-control circuit and the signal circuit by applying a sinusoidal test voltage in the gain-controlling circuit. A single test of this kind includes the effects of unbalance at all points in the gain range swept, and if the test conditions are suitable it affords a good overall evaluation of balance.

Measurements of both types have been made on the pulse-modulation compressor. In the first type, a 250-cycle low-pass filter was used, following the compressor, to reduce the carrier amplitude and thereby make the transient more easily seen. For a 10-db increase in input (5-db gain reduction), signal-to-thump ratios of 50 to 60 db were obtained.

The cross-modulation method is felt to be preferable for specifying un-

balance, because it does detect unbalance at all points in the range used. A figure of merit called "signal-to-unbalance ratio" is proposed to describe the performance of a compressor when tested in this manner. It is expressed in decibels and is defined as follows: Signal level is the maximum output level, with 10 db of gain reduction, at which some satisfactorily low value of total harmonic distortion of a 1000-cycle signal is produced. In the present case, this value is taken as 0.5%. Unbalance level is the output produced, in the absence of signal, by a 60-cycle control voltage which varies the gain reduction throughout the range of 0 to 10 db.

Using this cross-modulation test method, excellent signal-to-unbalance ratios have been obtained, along with freedom from the need for special tube selection and from the necessity for frequent rebalancing. Tests have shown that, except for the possible rejection of perhaps 10% of samples, tubes selected at random for the variable-gain stage (6SN7GT) will all produce optimum signal-to-unbalance ratios of 55 db or more. Operation over periods of a few hundred hours has indicated that the balance does not deteriorate more than 10 db during this length of time, and that the original figure can be readily regained by rebalancing. Although unregulated heater and plate supplies were used, line-voltage variations of 10% also increase the unbalance only about 10 db.

By adoption of pulse-modulation techniques, it has thus been possible to construct a compressor whose performance regarding thump is equal or superior to that of any now used in the most exacting applications, without the need for specially selected tubes or other components. Its moderate added complexity is felt to be of secondary importance in the light of its very significant advantages.

APPENDIX A

The modulating wave of Fig. 1 can be represented by the expression[3]

$$a = A_O\Big[k + \frac{2}{\pi}\Big(\sin k\pi \cos \omega_k t + \frac{1}{2} \sin 2k\pi \cos 2\omega_k t + \frac{1}{3} \sin 3k\pi \cos 3\omega_k t \ldots\ldots + \frac{1}{n} \sin nk\pi \cos n\omega_k t\Big)\Big], \tag{1}$$

where:

a = instantaneous value of gain,
A_O = gain value during "on" periods,
ω_k = $2\pi f_k$ = fundamental angular frequency of modulating wave,
k = ratio of pulse width to period of modulating wave.

The signal wave is:

$$e_s = E_s \sin \omega_s t. \tag{2}$$

An expression for the modulated wave is obtained by multiplying (2) by (1):

$$ae_s = A_O E_s\Big[k \sin \omega_s t + \frac{2}{\pi}\Big(\sin \omega_s t \sin k\pi \cos \omega_k t + \frac{1}{2} \sin \omega_s t \sin 2k\pi \cos 2\omega_k t \ldots\ldots + \frac{1}{n} \sin \omega_s t \sin nk\pi \cos n\omega_k t\Big)\Big]. \tag{3}$$

The first term, $kA_O E_s$, is the desired output. Each of the other terms is the product of a sine term, a cosine term and a constant, depending upon the value of k. The general term:

$$\frac{1}{n} \sin \omega_s t \sin nk\pi \cos n\omega_k t \tag{4}$$

can be rewritten as:

$$\frac{1}{n} \sin nk\pi\Big[\frac{1}{2} \sin (\omega_s t - n\omega_k t) + \frac{1}{2} \sin (\omega_s t + n\omega_k t)\Big]. \tag{5}$$

Since $\omega_k > \omega_s$, this is better rewritten as:

$$\frac{1}{2n} \sin nk\pi\,[- \sin (n\omega_k t - \omega_s t) + \sin (n\omega_k t + \omega_s t)]. \tag{6}$$

APPENDIX B

If the gain-vs.-input relation in the compression range is to be linear when expressed in decibels,

$$Db_O = kDb_i + c, \tag{7}$$

where:

Db_O = output level in db,
Db_i = input level in db,
k = slope of compression curve,
c = a constant.

On a numerical basis,

$$20 \log E_O = 20\,k \log E_i + c, \text{ or } \log E_O = k \log E_i + c', \tag{8}$$

where:

E_O = output voltage,
E_i = input voltage,
c' = a constant.

If the gain-controlling voltage is derived from and is proportional to compressor output, it is of interest to express voltage gain as a function of output:

$$\frac{E_O}{E_i} = f(E_O) \tag{9}$$

and determine the nature of the function f.

From (8),

$$E_O = c'E_i^k, \text{ or } E_i = \left(\frac{E_O}{c'}\right)^{\frac{1}{k}}. \tag{10}$$

Thus:

$$f(E_O) = \frac{E_O}{E_i} = \frac{E_O}{\left(\frac{E_O}{c'}\right)^{\frac{1}{k}}}$$

$$= c''E_O^{\left(1-\frac{1}{k}\right)}. \tag{11}$$

For 2:1 compression, $k = \frac{1}{2}$, therefore:

$$f(E_O) = c''E_O^{\left(1-\frac{1}{1/2}\right)}$$

$$= \frac{c''}{E_O}. \tag{12}$$

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Prints From 16mm Originals

By R. L. SUTTON, K. B. CURTIS and LLOYD THOMPSON

The introduction of reversal film — both black-and-white and color — made 16mm photography very acceptable for commercial use. Release prints in quantity were a problem. New printing equipment had to be designed and built, and new materials and techniques had to be improved. This paper will describe the methods used by The Calvin Company for producing high-quality release prints in quantity at the present time.

The introduction of black-and-white reversal film and, later, the introduction of color reversal film made 16mm photography practical. Through the use of these 16mm reversal materials, the field of motion picture photography was extended to many potential producers. Originally, it was thought that 16mm film would be for amateur use only. It was but a short time, however, until it was also being used for professional purposes. The amateur motion picture field has continued to grow and change, and today we find wide professional use of 16mm materials while the majority of amateur use is 8mm film. With professional use of 16mm materials, duplicate prints naturally were desired. This involved extensive work in printer design and also in photographic research to obtain better materials and methods for making duplicate prints from originals, both in black-and-white and in color.

Presented on October 17, 1951, at the Society's Convention at Hollywood, Calif., by R. L. Sutton, K. B. Curtis and Lloyd Thompson, The Calvin Company, 1105 Truman Road, Kansas City 6, Mo.

Much of the research and design of printers has been accomplished by the pioneers of 16mm film because they were intimately aware of the changes resulting from the growth and improvements in this field. Two important factors resulting from the improvement of 16mm materials vitally affected the design of printers for 16mm films: (1) the changes made in the physical characteristics of the original film; and (2) the fact that more and more printing exposure light has been necessary to print the new products as they were developed. Generally speaking, a printer designed to print one type of 16mm film often was obsolete almost overnight when another type of film showing new, different and improved characteristics was introduced; therefore, frequent changes in printer design were necessary in the early days of the industry. The problem was not so much in using the newer materials as in the difficulties of printing films as they aged. The problem of shrinkage and the effect of aging on film splices was often pronounced in older originals and it was difficult to find a printer

that would accommodate both normal and shrunken or aged originals. With the introduction of newer materials, the necessity for increasing the exposure light often demanded changes in printer design.

In setting up specifications for a printer, or a system of printing, it would appear that the problem would be simple. The problem is to make sound prints, in either black-and-white or color, that have consistently good quality at a speed that is economically feasible when using 16mm reversal originals. However, to accomplish these things, we believe a printer, or system of printing, should have the following characteristics:

1. The printer must give good contact and produce prints having good steadiness.

2. Sufficient uniform illumination must be available to print on such Eastman stock film as Type 5504, reversal duplicating; Type 7302, fine-grain release positive stock; Type 5365, black-and-white fine-grain duplicating positive; and Type 5265, color stock. If possible, additional illumination should be available to provide for future needs.

3. The printer must handle originals so that they are not scratched or damaged, even though large numbers of prints are made from the same original.

4. The printer must be able to make satisfactory prints from originals with normal and abnormal shrinkages. Our definition of these would be a shrinkage of from 0.01 to 1.5%.

5. A system of light changes for density corrections in the original must be provided, and this should be as foolproof as possible.

6. A minimum of maintenance should be required on the machine, and this must be done with a minimum of expense.

7. The printer, or system of printing, should provide for optical effects, in each individual print, as well as straight printing.

8. Provisions should be made for adding a filter pack to the light system. This should be far enough away from the light source so that the heat does not damage it over a long period of time.

9. Future requirements should be anticipated, insofar as possible, for such things as the color correction of individual scenes, when such methods become practical.

10. Means should be provided for an accurate measurement of illumination, both as to quantity and color quality of the printing light.

11. The power supply should be kept simple and, if possible, should operate directly from standard 60-cycle a-c current.

12. In designing, we feel that wherever possible standard parts, available on the open market, should be used to keep the original cost down, but more important, to allow for repairs with a minimum of trouble and expense.

13. The operation of all printers should be as simple and as automatic as possible so as to require a minimum of training for new operators, and thus reduce errors.

14. The printer should accommodate a minimum original print footage of 1200 ft and, if possible, it should handle 2000-ft rolls of originals and raw stock.

15. The take-up mechanism should handle both short and long lengths of film without trouble.

16. If the design of the printer is such that there is any tendency for the printing aperture to collect dirt, lint or hairs, an air blast should be provided to keep it clean at all times.

17. It would be highly desirable for the light-change cuing device to be standard. A notchless system is preferable. However, inasmuch as there is no standard for this, each laboratory has set its own standard as to where film should be notched. While it seems to be impossible to standardize the number of frames between the scene changes and the notch, it is in most

cases possible to standardize the type of notch. We have chosen the Bell & Howell narrow notcher for this purpose.

18. In making black-and-white reversal prints from black-and-white or color originals, reversal color prints from color originals, dupe negatives from either black-and-white or color originals, it is necessary that the light change between each step be greater than for printing positives from original negatives, as is customarily done in 35mm film. The design of a light-change system must take this into consideration.

19. The claw which moves the original and raw stock in a step printer should be exactly opposite the picture aperture in order that the framelines in the print be as nearly like those in the original as possible.

No doubt other specifications could be added and probably will be, as techniques and materials change.

We originally tried to solve our first printer problem by converting a Bell & Howell projector head into a printer. In many ways this did a good job, but it was not too long before it was obsolete. Several different printers were built and tried, but each had its limitations. We finally reached the conclusion that, for a system of printing suitable for our use, it would be necessary to have three types of printers:

1. A step-type picture printer.
2. A continuous-type picture printer.
3. One or more types of sound printers to add sound to the picture prints, made on the step- and continuous-type printers.

The Step-Type Printer

First, let us describe the step-type picture printer and see how it meets the specifications. By looking at Fig. 1, you will immediately recognize that a number of standard parts have been used to build this printer. Some of these parts, such as gears, which cannot be seen in Fig. 1, are also standard. An inspection of the printing gate will show that the raw stock and the original film are handled separately so that tension is applied to each of the films. They are also edge-guided, separately. This was done in order to assure a steady print and to eliminate side weave. The printing gate is curved in order to remove the curl in the original film, so that good contact could be made with the raw stock. By using this method to flatten the original film for good contact, it has been possible to relieve the printing gate at all points where the original film would touch metal. Experience has shown that the only way to keep from scratching film is not to let it drag on anything, regardless of how highly polished it may be. Such a surface will eventually cause trouble.

Certain types of duplicating film, especially Kodachrome, have a tendency to curl or cup at low relative humidities, which means that good contact is not always possible in the middle of the picture. This tendency can be minimized greatly by maintaining the relative humidity in the printing room at about 50%. To eliminate this difficulty, a special pressure shoe was designed to hold the raw stock against the original in the center of the film. Thus, the problem of contact and steadiness was solved in this particular printer. This type of gate is very easy on the original film. Damaged sprocket holes, or other defects in the original, may cause it to lose a loop, but the original is not damaged. Examination of the printing gate will show that the pulldown claw is exactly opposite the picture frame, thus making it possible to keep the frameline as nearly like the original as possible. Productions photographed with several different cameras having widely different framelines will cause trouble. About the only way to minimize such trouble is to use an especially wide frameline in the printer at the time prints are made from such originals.

In order to secure optical effects in

Fig. 1. The step picture printer with light-change board.

the prints, The Calvin Company has for a number of years printed from A and B rolls in combination with A and B rolls of optical-effects mattes (Fig. 2). This means that our printers must be able to run the optical-effects mattes. This system has been described before,[1] and since most people are acquainted with such mattes only a few things need be said here. The success of the system depends upon the optical-effects mattes being projected onto the back of the original film as it is printed on raw stock. Such mattes cannot be run in contact with the original, as has been done in 35mm, for several reasons. Trying to run three pieces of film through one film gate causes a lot of trouble and in addition, any dirt, scratches or slight defect in the matte will be printed into the final print quite easily. By projecting these mattes and throwing them slightly out of focus, nearly all of these difficulties have been eliminated, and doing so completely avoids the trouble of trying to run three pieces of film through one gate at the same time.

A standard Bell & Howell silent projector with certain modifications was used as a matte runner, and as a light source for printing. In order to use a projector for this purpose it was necessary to disconnect the regular projector motor and use an external constant-speed motor to drive the ventilation fan, because the regular projector motor would not stand up under such long, hard service. It was also necessary to construct a special tube which would fit very close to the aperture of the projector in order to eliminate the majority of the stray light which escapes from the projector in the printing room. A method had to be provided for carry-

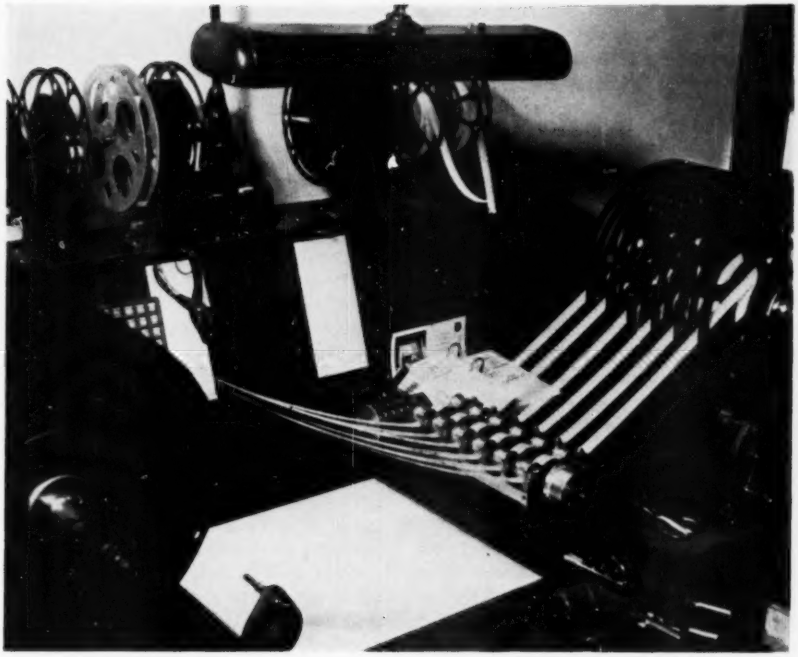

Fig. 2. Optical-effects and density mattes, A and B rolls, etc., are checked on this multiple synchronizing equipment.

ing the heat from the lamp out of the printing room and, in doing this, we have also trapped the stray light at the top of the lamphouse to prevent its entering the printing room. The optical system for projecting the effects mattes is a standard projection lens. We use the largest-aperture lens available for the focal length involved to gain efficient light transmission. The color-correction filters used in the filter pack are placed in the printer head of the mechanism as far away from the light source as possible, and there has been practically no damage caused by heat from the lamp affecting these filters. They are stable over a period of many months.

A special device has been made which can be locked over the printing aperture to hold a photoelectric cell for measuring illumination. This photoelectric cell is connected to a galvanometer. Furthermore, the device is fitted with a multiple slide carrier which holds color filters as well as neutral density filters. When the illumination level is to be measured the neutral density position on the carrier is used. The other three positions are used for checking the quality of the printing light for color printing and for matching individual printers. This device has previously been described by P. S. Aex.[2] We have added the fourth slide with the neutral density filter for checking the quantity of light, and have found this to be a useful addition.

Take-ups on all machines handling film have always been a problem. At the time our present printers were built we were more satisfied with the

constant tension cloth belt type of take-up, as used on several projectors, than any other we had ever used. In general, these have been very satisfactory. However, torque motors have been used on a number of take-up mechanisms in the last few years, and new printers are now being built with torque motors as take-ups. Results indicate that these will be even more satisfactory.

Light-Change Devices

Light changes are made in this printer by a resistance type of board (Fig. 1). We realize that, theoretically, a resistance board should not be used in making density correction in color prints, but we have both types of light-change devices in our laboratory, as will be described later. Experience has shown time and time again on tests we have conducted that, for all practical purposes, there is no difference between the changes made with a resistance board and those made with a neutral density type of correction. For that reason, we have continued to use this type of system on the step printers. A change of illumination, or a change of materials or processing in the future may make this statement void.

Originally, drop-type light boards were used with all the difficulties encountered with such boards. When it was necessary to replace these we thought it desirable to make a number of changes, and so another type of light board was built. The idea is not new; but, on the other hand, we do not believe that these boards are generally available on the open market. A piece of 35mm positive film is punched and used in the mechanism to actuate the light changes (Fig. 3). Since there is not enough room on a piece of 35mm film to make enough punches to allow for 18 different light changes — which is the standard we use — it was necessary that we make a punching machine that would punch these light changes in code. By looking at one of these pieces of film it can be seen that the first six light changes are made by simply punching a hole in the proper place for numbers one to six, but number seven light change is one and two, number eight is one and three, etc. By using this code system, it has been possible to get all the light changes on the strip of 35mm film. In addition, we have room left over for several holes which can be used to add automatically the corrective filters to the light beam at the same time the light changes are being made, if such changes are desirable. Such a system of making color correction is not in general use in the field as yet, although most laboratories have some method of doing this if the occasion demands it. As color processing becomes more refined and as other new materials are added for duplicating purposes, we feel the time will come when color corrections will be desirable and probably necessary.

Such a light board has a number of advantages over the conventional drop-type board. There is no limit to the number of light changes that can be made in one reel of film. In other words, a hundred changes can be placed in one 400-ft film if necessary. This system is highly desirable when printing long lengths of film. Such a system also means that once the film has been correctly cued, it is impossible for the operator to set up the board incorrectly. Furthermore, it eliminates hours of wasted setup time. With this system it is only necessary to thread the strip of film into the light-change mechanism, turn it up to a point where a signal light comes on, showing that it is in proper position to print, and then proceed to print. This cuing strip is kept with the original film at all times and, in the future, when a print is wanted, all that is necessary to set up the board is to thread in the strip and proceed to print. Built into the light board is a voltage regulator which automatically keeps the voltage level constant. A variac is also included in the circuit so that small

Fig. 3. This punch is for making the light-change cue strip and also color-correction changes. The upper row of keys is for correction.

variations in normal light can be made in order to correct small changes in the filter pack, etc. By measuring this normal light with the photoelectric cell circuit, previously described, it is possible to keep the printing normal quite constant.

Built into the printer head is an air-blast mechanism which constantly blows against the printing aperture, thus keeping it free of dirt and lint which might otherwise accumulate.

This step printer, we believe, meets the specifications we outlined previously and can be used for making Kodachrome prints, reversal prints, dupe negatives and, with the proper aperture, black-and-white positive prints. Such a printer is necessary for a small quantity of prints from one original and for special purposes, such as the making of dupe negatives.

The Multimatic Printer

There is, however, another problem that we do not feel the step printer answers as it should. This is the problem of large-quantity print orders from the same original. For this purpose we have designed a continuous-type printer which is known as the *multimatic* printer (Fig. 4). This is a three-headed printer which was originally designed for making color sound prints with optical effects and light changes, automatically. The machine runs in both directions and once it is threaded with the proper optical-effects mattes and density-change mattes

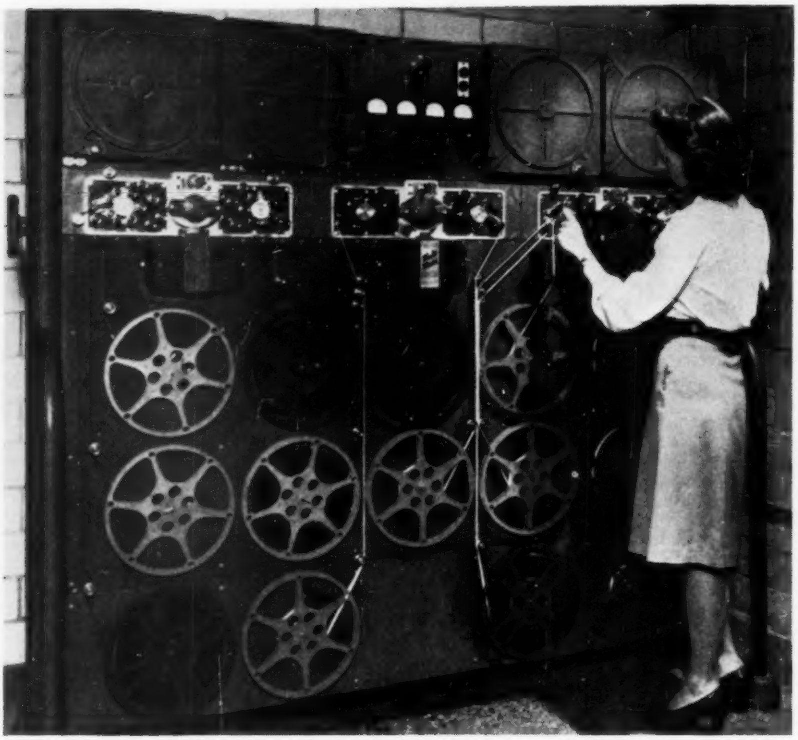

Fig. 4. The Multimatic printer threaded for making sound Kodachrome prints with optical effects and light changes. The optical-effects and density mattes are on separate rolls on this setup.

it is not unthreaded again until the prints are finished or the originals are taken off for cleaning. The operator simply stops the machine at the end of each print, threads on more raw stock, and makes another print going back in the opposite direction. This way, there is never any rewinding of originals. In addition, the machine has the advantage of being able to use odd lengths of film which are a problem in Kodachrome printing. The printer may be backed up at any point, utilizing odd lengths of raw stock. Once these have been returned from processing they can be cut in at the proper point and spliced together, thus using raw stock with a minimum of waste.

This machine has been built to handle 1200-ft rolls of original and raw stock, and runs at 72 ft/min in either direction. Light-change boards for such a machine would complicate the job and probably give a considerable amount of trouble. For this reason, we made a special density matte containing the light changes which are run along with the optical-effects mattes, thus producing the desired effects and light changes in the print. These density mattes are made on a Bell & Howell Model J printer which has been remodeled for

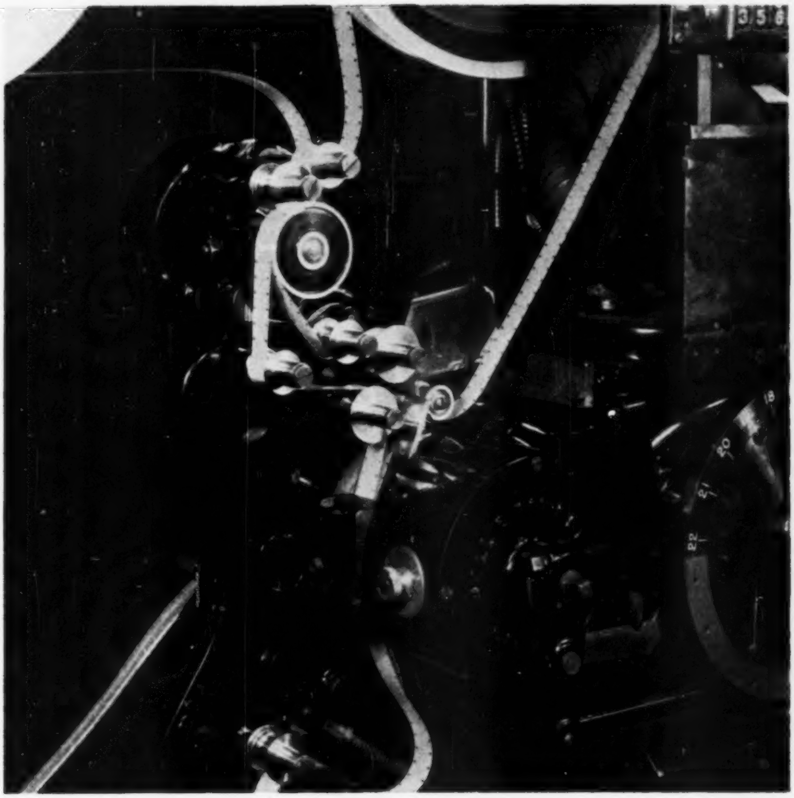

Fig. 5. Modified Bell & Howell Model J printer for making density mattes. The cue film is threaded around the gate.

this work (Fig. 5). Such a matte system, of course, does not change the color temperature of the lamp. As we have said previously, prints made by this method do not show any particular difference from those made with the resistance type of board on Kodachrome film as we know the process today. The printing on this machine is done on a 40-tooth sprocket which has been designed to accommodate film shrinkages up to 1.5%. Contact is maintained with a rubber roller at the printing aperture. Here again the problem of curl in Kodachrome Duplicating Film made it necessary to provide this rubber roller for consistent operation. The shoe type of contact which is generally used on continuous printers was too critical in adjustment and too hard to keep in adjustment to be satisfactory.

Printing is done by contact on the 40-tooth sprocket with the mattes printed optically from the opposite side of the sprocket below. The filter pack is placed between the objective lens and the printing aperture. Beneath the matte aperture, and enclosed in the lamphouse, is a right-angle prism which turns the light up from a horizontal

source. Thus, the lamp occupies a normal upright position. Beside the objective lens, there are three condensing lenses. As in the step printer, the original film does not touch metal at any point, so the chance of scratching the original is at a minimum. Many scratches or cinch marks are caused in rewinding original material. Since the originals are not rewound between prints when they are made on this printer, the danger is largely eliminated. The printer was designed to make a large number of Kodachrome prints from a single original, so that second-generation prints would not have to be used as originals. We do not know how many prints can be made from one original on this machine, because we have never made a large enough number to find out. We have printed over 600 Kodachrome prints from one original, and from all appearances a good many hundreds more could be made from it. This does not, of course, mean that that many prints could be made from any original, because we frequently receive originals which are in bad shape before we ever start printing them. However, when the originals received for printing are in good shape and good splices have been made, we have had almost no trouble in making as many prints from them as any customer might want.

The *multimatic* printer is also suitable for making prints from dupe negatives and sound tracks. When a printer is used for this purpose only two heads are used — one picture head and the sound head. Of course, the optical-effects mattes are not used because both the optical effects and the light changes have been incorporated into the dupe negative. Nearly all black-and-white release prints are now made by using a dupe negative from original reversal black-and-white or color, and then printing on fine-grain positive. Black-and-white reversals are used on only a few special orders.

The third type of printer which we must use is the sound printer. Prints made on contact step printers have the sound added from a Maurer optical printer. Before the dimensional characteristics of sound-film base were stabilized, this type of printer was highly desirable as it would handle originals with various degrees of shrinkage. When the *multimatic* printers were built, provisions were made for printing the sound optically. However, tests at that time did not indicate any advantage would be gained by this method, and still other tests made over a period of years have confirmed this point. These tests were made in our own laboratory and in other laboratories, using the optical system of sound printing. Therefore, the sound on the *multimatic* is printed by contact.

An Optical-Effects Printer

At the present time, we are putting into operation a new machine which was designed to be used with the *multimatic* and step printers. This is known as the Curtis Automatic Effects Printer (Fig. 6). This machine is an optical-effects printer to be used for printing the optical-effects mattes. Up until the present time all these mattes have been edited and spliced to the picture by splicing together optical effects with black and clear film. Instead of making up a matte in this manner, we now punch both edges of the workprint with cue marks and the workprint is used to cue the optical-effects printer. The printer is then loaded with positive film, turned on, and it automatically prints the mattes with wipes, fades and dissolves, all in one piece of film. As soon as this film has been developed it is then ready for checking and printing. In addition to printing the optical effects onto this piece of film, we can add a density wherever necessary so that when we have a final matte for printing it will make both the optical effects and the light changes.

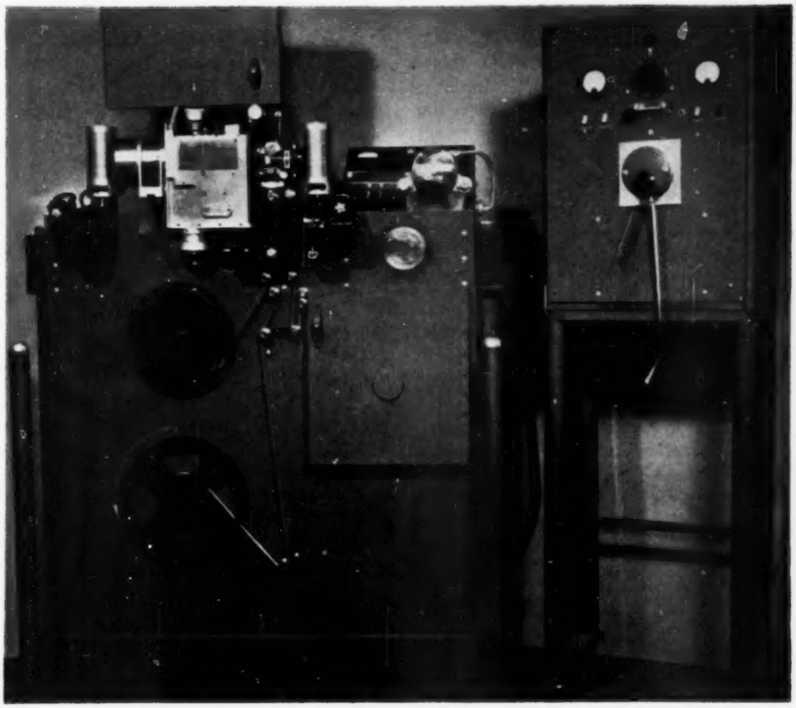

Fig. 6. Optical-effects—density-matte printer. The light-change board is threaded with a punched 35mm strip for selecting the proper printing exposure for the density matte. A second 35mm punched strip (hardly visible in photograph on right top of printer) is used as a selector for the proper optical effect.

How does the machine operate? Basically, it is built around a peculiar arrangement of movements that control the effects blades. Each effect, with the exception of the straight wipes, has a set of these movements which combine the four standard effects of that type through selective triggers into a single unit with only one set of movements. Since the straight cut is not considered an effect, the omission here of a set of movements is not another exception, even though the dowser, responsible for the straight cut, is also used as an integral part in every effect.

First among the parts involved in each set of movements is a planetary-gear type of clutch which is geared direct to the main driving shaft of the machine. Upon a given signal it is released for a single cycle at a rate proportional to the number of film frames involved in the effect being driven. In turn, an eccentric pin, geared to the clutch, drives a movement known as the Walschaert gear. The object of the Walschaert gear is to allow admission to a new source of driving power, emanating from a double-acting, rotary-type solenoid. This quickly reverses the effect back to its normal position or, if the reverse operation is involved, out of its normal position before or after the planetary-gear clutch

has released its cycle of motion, let us say, causing the effect to close. The solenoid, acting through the Walschaert gear, quickly opens the effect back to its original position. But, before the solenoid can work, the dowser chops off the light, holding its closed position until the next signal reverses the continuity of operation and opens it. Each set of movements is extremely versatile.

During the closed position of the dowser, or any other blade, for that matter, no light can reach the film. Hence, the film will be transparent during this period following its development and will allow printing to be done through it. Therefore, the image of a closing blade actually opens a scene, while the image of an opening blade closes the scene. This commonly understood inversion is only one among many encountered in the machine. The opening and closing of each sequence is continuous throughout a film and is the means by which release printing can be done, subsequently, at first one gate and then another without the show of a splice. The dowser is the only automatic instrument in the machine that needs to be positioned before a run, and that is done in the course of preselection. All other effects hold a normal open position when not in use.

The mechanical movements just described entail considerable electrical equipment which includes a signaling system. Its manipulation throughout one run is made easy, however, by simply edge-notching the workprint for each effect and/or timing change as desired and by perforating two 35mm films as selector strips. Since two combination mattes (timing and effects) are required for each show, both edges of the workprint are notched as A and B, respectively, and two more selector strips perforated to match for the second run. The use of both edges of the workprint avoids making an extra cue film and retains the advantages of notching to an actual picture continuity.

Preselection is not relegated to any one department or person. It is an accumulative process, developed over the preparatory printing route. The signal originates with the workprint because, when edited, the splices between scenes represent the absolute, with reference to the desired effect, if any, penciled on the film in code. This eliminates the script from further use in finishing the picture. When the originals are being critically scanned for timing in the laboratory, the estimate of correction needed for each scene is recorded on a cue sheet in terms of light-change numbers for future use in punching the selector strips. The workprint is also included on the same gang synchronizer, and is marked for edge notches which coincide with the timing tabulations entered on the cue sheet. Actual notching, however, is done later when the workprint is returned to editing with the cue sheet. Here the effects and timing continuities are matched so that a single notch will accommodate both as often as possible. Also, the effects cues are tabulated on the same cue sheet which is then sent back to the laboratory where it is used in punching the selector strips. Finally, the strips are brought together with the workprint at the machine for the run.

To insure proper placement of the notches, two standard Bell & Howell notchers have been cut down and mounted side by side into a single unit (Fig. 7). The two blades, marked A and B, respectively, face one another across one film path with edge guides intact. In this path a single pilot pin is mounted between the blades to insure positive registration to the notch in relation to the sprocket holes. A graduated scale is mounted off to the left and points out where the splice between scenes shall be placed when notching for each type of effect. Furthermore, the scale translates the effects code, penciled on the film at the splices, into the particular selective station numbers con-

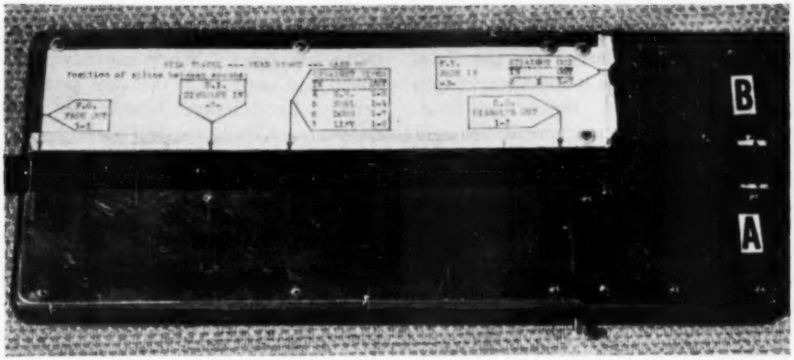

Fig. 7. Special punch for notching cue film, or workprint, for Curtis effects—density-matte printer.

cerned. Index buttons on the A and B edges of the notching block are manually pushed back and forth to remind the operator of the particular track (A or B) a scene or sequence is relegated to as the alternations proceed, otherwise the picture continuity of the workprint is obviously without this information. The location of timing notches depends only upon the marks penciled on the film in timing, which may be at the splice with certain opticals or apart within the scene proper. Because timing is included in each combination matte, there are no edge noches in the originals, which inadvertently serves to circumvent the lack of a notching standard as discussed previously.

In this respect, it is well to note that, while the entire process is really quite simple, there is a definite technique involved in both preselection and machine operation that readily lends itself to a minimum of schooling among the personnel taking part.

The size and arrangement of the perforations in both selector films provide room at each step for ten selective stations, positioning being equal to the spacing of the sprocket holes. This gives the workprint notch control over 20 selective stations. Of the ten timing stations only six are used to control a wide range of light changes, while of the ten effects stations only eight are at present in use, leaving an ideal situation for future development. Preselection is done in the laboratory, as previously stated, on a punching machine, the keyboard of which resembles a typewriter.

Timing is arrived at through coupled resistors in series with the lamp, selection for intensity being directed through a relay system interlocked with the various taps in the resistor. There are 18 different light-intensity levels available, each arrived at as a plus or minus relative of the ninth level, which is manually preset through a variac. Since timing requires a finer gradation of light, the lamp is located on the emulsion side of the raw stock which is separated from the constant-burning effects lamp, located on the base side. However, the effects light also requires accurate setting because of the fade effect which is a form of the photographic wedge. Both lamps converge their rays along the axis through separate optical systems onto the same gate, which is so constructed that it has an aperture on each side of the film. Since certain effects are made optically, such as the wipes, there is an objective lens on the effects

side which makes a camera of that part of the printer. This cameralike head has a dissolving shutter for the fades and a dowser for both the straight cuts and effects auxiliary. Beyond this head, large condensing lenses spread the light field for the effects. The timing system has only a small condenser lens, but there is a density filter pack included. Both lighting systems have separate voltage regulators, transformers for low-voltage lamps, manually controlled variacs, voltmeters and ammeters.

The machine is of the step type and its product will eliminate the separate light-change matte which was previously used on the multimatic printer.

Experience has shown that most of the optical effects wanted today are fades, dissolves, right and left wipes, and up-or-down curtain wipes. The printer has been built to provide these, automatically, on signal. Any special wipe can, of course, be cut into a printed matte if necessary. But, if this is done, a separate density matte will be required.* We will be able to use this matte with the light changes on step printers. Once a picture has been set up for printing, in this manner, it can be printed on either type of printer with the same matte producing the opticals and light changes in the final print. When printed optical effects are used with the step printers, density light-change boards are unnecessary. This, we feel, will be an advantage because it will eliminate any mis-lights. We also feel that the elimination of splices in the mattes will be a distinct advantage.

We do not necessarily believe that this system of printing is suitable for every 16mm laboratory, but it has been successful for us. Neither do we think it is the final answer, because new products will probably change some of our methods. However, we believe that we know how we can make conversions on present printers. And, where conversions will not work, we have ideas on how different types of printers can be built for new processes which have not yet been developed to where they may be introduced commercially.

* Since this paper was originally written, a method has been discovered which permits other types of wipes to be printed directly.

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High-Constant-Speed Rotating Mirror

By J. W. BEAMS, E. C. SMITH and J. M. WATKINS

The rotating mirror is magnetically suspended in a high vacuum and spun by a rotating magnetic field. The mirror is accelerated to full speed in a way similar to that of the armature in an induction motor, but at running speed it performs as an armature of a synchronous motor. The frequency of the rotating field is determined by a piezoelectrically controlled circuit. Also it is free of hunting. The maximum rotational speed of the mirror is determined only by the strength of the mirror. Mirrors are described which rotate at 20,000 rps.

In a great many problems, where it is necessary to study accurately phenomena which occur in very short intervals of time, it is desirable to have a high-constant-speed rotating mirror.[1,2] It is particularly important that not only the number of revolutions per second of the mirror must be known with high precision, but the mirror must be free of so-called hunting or rapid variations in speed. This latter requirement of freedom from hunting is usually almost impossible to attain in practice, especially where the friction on the mirror or bearings requires that the drive deliver considerable power, i.e., when the frictional torques and the driving torques are large, small asymmetries in either give rise to hunting of the rotor. In the rotating mirror arrangement described in this paper, the total frictional torque is very small with the result that the speed can be made extremely constant and hunting, if present, is too small to be observable.

Presented on May 2, 1951, at the Society's Convention at New York, by J. W. Beams, E. C. Smith and J. M. Watkins, Rouss Physical Laboratory, University of Virginia, Charlottesville, Va. The research project upon which this paper is based was supported by Contract NOrd-7873 with the Navy Bureau of Ordnance.

Experimental Arrangement

Figure 1 is a schematic diagram of the apparatus, while Fig. 2 is a photograph of the suspended mirror with the vacuum chamber and one drive coil removed. This arrangement is the outgrowth of a series of experiments, using magnetically suspended rotors or centrifuges in a vacuum, carried out at the University of Virginia over a number of years.[3–7] The mirror R made of high-strength ferromagnetic material is suspended inside a glass vacuum chamber by the axial magnetic field of the solenoid S situated above the chamber. The vertical position of the rotor is

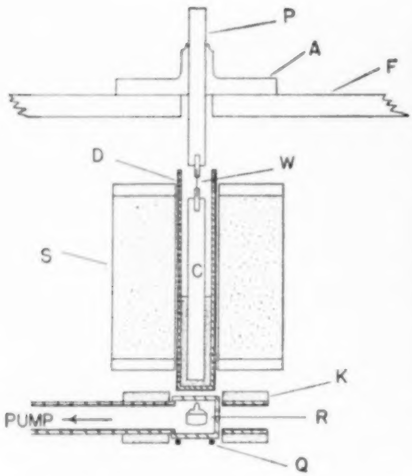

Fig. 1. Schematic diagram of high-constant-speed rotating mirror arrangement.

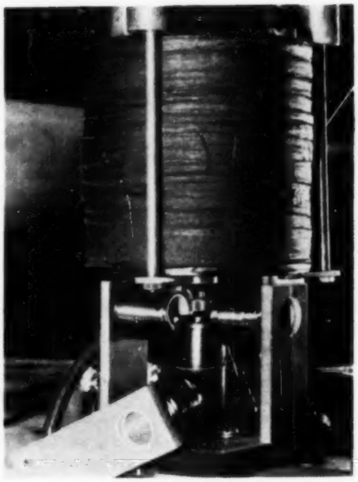

Fig. 2. Suspended mirror, with vacuum chamber and one drive coil removed.

maintained by the automatic regulation of the current through the solenoid S, while its horizontal position is determined by the symmetrically diverging magnetic field. The mirror R is spun by two pairs of coils K which produce a rotating magnetic field. The small coil Q is part of a tuned grid–tuned plate radiofrequency oscillator (Fig. 3) which regulates the current through S. It is so arranged that when the rotating mirror rises, the current through S decreases, while when it falls, the current in S increases in such a way as to maintain the mirror at the desired height without observable hunting. The steel cylindrical core C of the solenoid S is suspended by a small wire W from the adjustable support P. The core C is surrounded by a damping fluid as shown and serves to damp any horizontal motion of the rotor.

Suspending Circuit

The circuit, which automatically regulates the current through the solenoid S in such a way as to maintain the rotor at the desired vertical position, is shown in Fig. 3. The pickup coil Q is in the grid circuit of a 5-mc partially neutralized tuned grid–tuned plate oscillator. If the rotating mirror R moves downward and approaches the coil Q, the latter's impedance, with the proper setting of the oscillator, is changed in such a way as to lower the amplitude of oscillation in the circuit. This gives rise to a so-called error signal which is detected by a cathode-follower detector and appears as a reduction in potential across the resistance R_{12}. A portion of this potential change appears on the grid of a 6SJ7 which is one-half of a two-pentode mixer. Subsequently, this signal increases the potential on the grids of the three 6L6's in parallel, which increases the current through the solenoid S and in turn raises the rotating mirror R.

In order to prevent vertical oscillation of the rotor R the "error" signal is differentiated by the resistance R_{11}-capacity C_7 combination and mixed with the original error signal. Also,

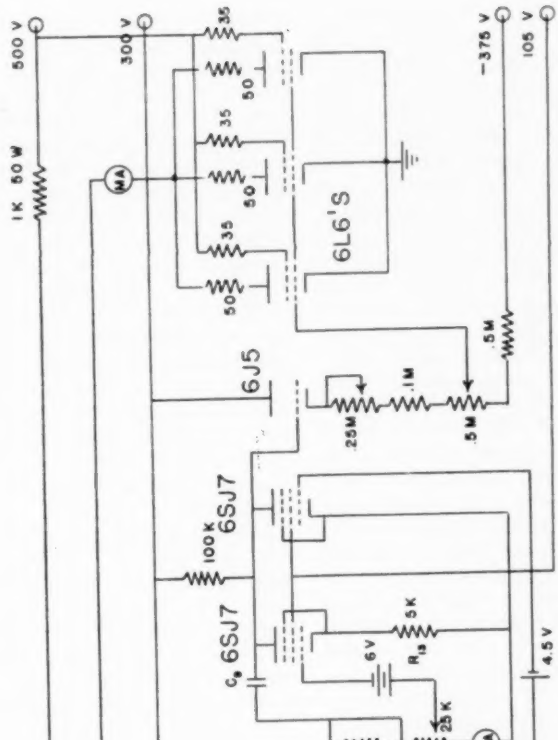

Fig. 3. Diagram of tuned grid-tuned plate radiofrequency oscillator and support.

the use of two 6SJ7 pentodes as mixers together with the negative feedback through resistor R_{13} and condenser C_9 produces increased stability. The power supplies were of the conventional regulated degenerative type.[8] The regulation of the 500-v supply is less critical than that of the 300-v supply so the latter is stabilized from the former. A variation of from 100 v to 135 v in the line voltage produces less than a 10-v change in the 500-v supply which in turn produces less than 0.02 v in the 300-v supply. The −375-v supply is obtained from a conventional transformer rectifier with condenser input filter system and stabilized with two VR 150's and one VR 75 in series.

The solenoid S consists of 25,000 turns of No. 28 insulated copper wire wound on a bakelite frame. Its inductance is 19.5 h (henrys) and its resistance, 1010 ohms. The cold-rolled steel, cylindrical core C of the solenoid ($\frac{7}{16}$ in. in diameter and $3\frac{7}{8}$ in. long) is suspended by a $\frac{5}{32}$-in. length of hardened 0.018-in. diameter piano wire W. The height of the core C is adjusted with a brass plunger P which fits into a brass disk A. The disk, which slides on the frame F, is adjusted by setscrews to the proper axial position so that the core remains approximately on the axis of the solenoid S when the current is raised to maximum value. The length of the core C and wire W are adjusted so that the period of the pendulum so formed is approximately that of the rotor S when given a horizontal displacement. The core hangs in a "dash pot" (a glass test tube flattened at the lower end and filled with SAE No. 10 motor oil) and damps any horizontal motion of the rotating mirror R. No motion of the rotor either in a horizontal or vertical direction can be detected by a 50× microscope focused on the scratches of the suspended mirror.

Rotating Mirror

For greatest stability of magnetic support it is desirable (although not absolutely necessary) to make the rotor as long or longer in the direction of the axis of spin than in the radial direction. On the other hand, for rotational stability, the moment of inertia around the axis of spin should be larger than that around the radial or perpendicular direction. Added to this, the rotor should be symmetrical around the axis of spin. It was found that a sharp cone on top of a short cylinder proved to be a very stable configuration. The faces of the mirror were ground on the cylindrical surface and the sharp cone concentrated the magnetic flux in the proper way to give stability. The edges of the top and bottom of the cylindrical portion were slightly beveled to prevent discontinuities (resulting from the mirror faces) from affecting the pickup coil Q.

The first mirrors were made of magnetic stainless steel (Carpenter 2B stainless 400). They were machined to shape and then heat-treated by the standard procedure to give good mirror surfaces and high strength. They were next ground to exact shape and the mirror surfaces lapped and polished. They were flat to roughly 0.2 wavelength of sodium light. Rotors of 0.5-in. diameter with mirror faces $\frac{1}{4}$ in. × $\frac{1}{4}$ in. were used successfully for long periods at 16,000 rps, but exploded at 18,500 rps. As a result the stainless steel has been replaced by hard high-strength alloy steel with the mirror faces covered with a very thin coating of aluminum. Ball bearings ground to the proper shape were found to be satisfactory when care was taken not to remove the temper during the grinding process. The mirror used at 20,000 rps was 0.5 in. from the bottom to tip of the cone and each of the six mirror faces was 0.25 in. in diameter. The first type of mirror is shown in Fig. 2. The rotating mirror was surrounded by an all-glass vacuum chamber with an optically flat glass window, through which the light passes, sealed on with low-vapor-pressure vac-

uum cement or wax. The chamber was evacuated by a standard forepump, diffusion-pump, cold-trap arrangement.

Driving Circuits

A schematic diagram of the drive circuit is shown in Figs. 4 and 5. The drive frequency is determined by a piezoelectric crystal-controlled electron-coupled oscillator operating at a frequency of 100,000 cycle/sec (Fig. 4). The crystal operates in a thermostat-controlled oven to improve stability. The oscillator is calibrated by zero-beating the 100th harmonic with the 10-mc wave broadcast by radio station WWV of the National Bureau of Standards. The oscillator may be tuned over a very narrow range and, in practice, set to give the lowest practical beat frequency. This procedure allows the oscillator frequency to be determined to about one part in 10^8. However, the published precision of WWV is only five parts in 10^8, so that when radio transmission irregularities are considered, the precision of the oscillator is not known to perhaps better than one part in 10^7. In practice, the oscillator circuit is operated for long periods of time and the drift is extremely small. If it becomes necessary to determine the frequency to better than one part in 10^7, it will be necessary to have a laboratory standard.

The output of the buffer amplifier of the oscillator is fed to a multivibrator frequency divider. The output of the multivibrator is a square wave of frequency $1/n \times 10^5$ cycle/sec, where n is an integer. The divider was designed for $n = 5$ or 6, i.e., frequencies of 20 kc or $16\frac{2}{3}$ kc, but other division ratios are easily obtained. This square wave is fed through an amplifier which serves as a filter. The resultant sine wave is passed through a phase-splitter and buffer-amplifier. The output (Fig. 5) is then amplified and transformer-coupled to the power tubes which operate as class C amplifiers with the drive coils resonant with the proper capacitors as the plate load.

The speed is measured by a method shown schematically in Fig. 6. Light is reflected from the mirror faces into a photomultiplier cell. This signal is amplified and applied to one pair of plates of an oscilloscope. The comparison frequency is applied to the other pair of oscilloscope plates so that the resultant Lissajous figure gives the frequency relationship. The comparison frequency was usually a standard audio-frequency oscillator except at operating speed, where the drive frequency or WWV was used as a comparison.

Operation

The procedure in starting the rotating mirror is to turn on the crystal oscillator in the drive circuit several hours before operation so that it will have sufficient time to reach thermal equilibrium. In the meantime, the pumps are started and the chamber surrounding the rotor evacuated to 10^{-6} mm Hg pressure or below. The mirror is then supported and the power applied to the driving circuit. In practice the support circuit approaches equilibrium in a relatively short time. The rotating field produced by the two pairs of coils K (Fig. 1) induces eddy currents in the mirror and it starts spinning. Consequently, the mirror acts as a high-resistance armature of an induction motor and continues to accelerate.

When the mirror speed approaches within about 40 rps of the frequency in the coils K, the rate of acceleration falls off, but if the pressure in the vacuum chamber is below 10^{-6} mm Hg the rotating mirror will continue to accelerate until its rotational speed approaches closely enough to the frequency of the rotating magnetic field to "lock in." When this occurs, the rotating mirror operates as an armature of a synchronous motor and spins without observable hunting at a rotational speed equal to the drive frequency. Consequently,

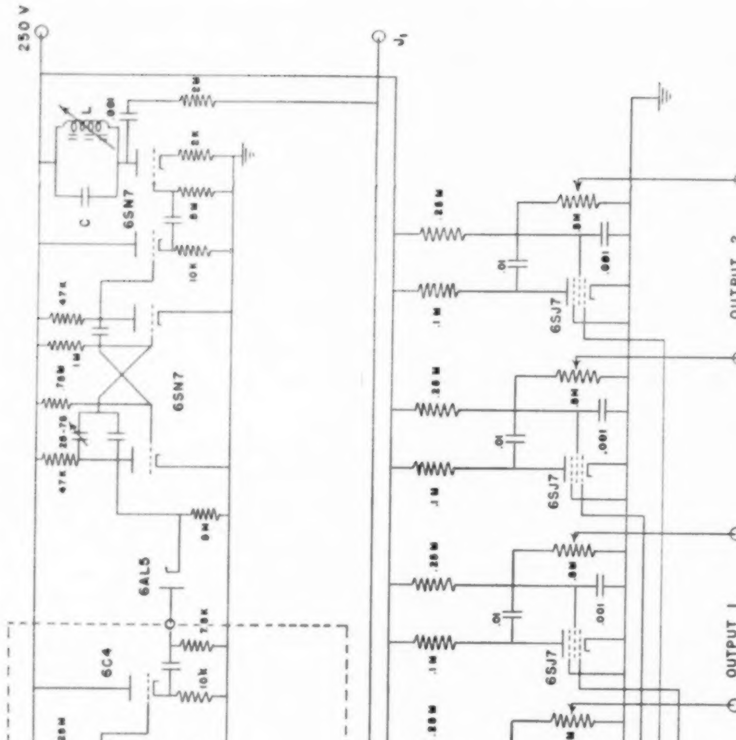

Fig. 4. Drawing of crystal-controlled oscillator and multivibrator frequency divider.

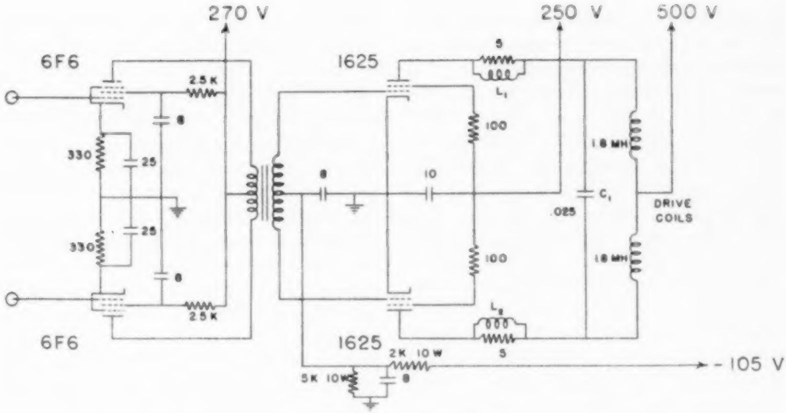

Fig. 5. Drive amplifier.

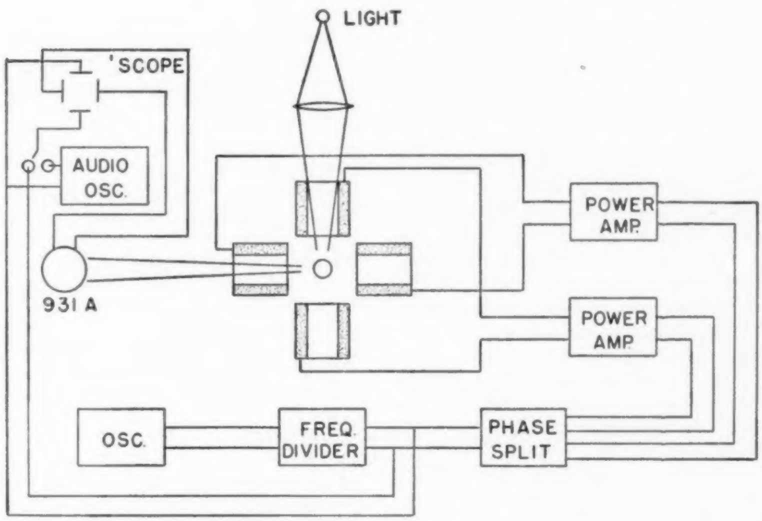

Fig. 6. Scheme of speed-measuring method.

the rotational speed of the mirror is known with the same precision as that of the master driving oscillator. Usually it requires more time to accelerate the rotating mirror the last 40 rps than to bring it up to this speed since the torque falls off very rapidly as the "slip" becomes small. As a result, it is usually advantageous to disconnect the crystal oscillator from the phase-inverter and substitute an audio oscillator during the acceleration period. In this way the drive frequency is set at 50 or 60 cycles above the desired running speed. When

the speed of the mirror slightly exceeds the desired running speed, the audio oscillator is disconnected and the crystal control substituted. The mirror then decelerates slowly and "locks in." When the mirror first "locks in" it hunts with a considerable amplitude, but in a few minutes this damps out and becomes too small to observe (less than 10^{-3} radian/sec). Since the rotor speed is over 10^5 radian/sec the error introduced by hunting is less than one part in 10^8.

With the circuit of Fig. 5 and a power input to the coils K of 150 w or 1.6 amp in the coils, the mirror accelerated at the rate of approximately 1000 rps/min until the "slip" frequency became about 50. However, with this much power input it is necessary to cool the coils with a small fan. On the other hand, when running speed is obtained, the power in the drive coils should be considerably reduced. The temperature of the mirror increases a few degrees during the acceleration period if the power input is not greater than indicated above. At running speed the rotor temperature decreases slowly to practically that of the surrounding walls. By removing the driving torque and permitting the mirror to "coast" freely, the deceleration is found to be extraordinarily small. As a matter of fact, the measured deceleration can be accounted for as due only to the friction of the residual gases surrounding the rotor. As a result, in order to bring the mirror to rest, it is necessary to reverse the direction of the rotating magnetic field and drive it down, otherwise it would take a very long time for the rotor to come to rest.

The above rotating-mirror arrangement is especially useful when phenomena which occur in very short periods of time must be studied with precision. It was developed for photographing the successive stages of sparks in different gases and the various stages of vacuum sparks. Also, it is being applied in a study of the velocity of light through liquids as a function of the wavelength of the light. Due to the high precision with which the rotational speed is known (one part in 10^7) and its freedom from hunting, the arrangement is almost ideally suited to the measurement of the velocity of light in a vacuum. However, for highest precision, the light path should be of the order of a mile in length and this distance is very difficult to measure and maintain with a precision of one part in 10^7. The maximum rotational speed of the mirror is limited only by the mechanical strength of the mirror. Consequently, by reducing the size of the rotating mirror higher speeds can be obtained. At the present time, a rotating mirror which spins at 10^6 rps is under development.

Acknowledgment: It is indeed a pleasure to acknowledge the valuable help of Dr. P. B. Buck during the initial stages of this work.

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Discussion

M. L. Sandell: If you wanted to slow up the rotor faster than happens directly from friction, could you do it by reversing the field?

Dr. J. W. Beams: Yes, that is the best way of doing it.

E. Salzberg: I would like to know whether the techniques you have developed in supporting a rotating object have found any application in industry or commerce?

Dr. Beams: Well, I don't know. This is a research tool as far as I know. Besides, in the spinning of mirrors, I think probably it will be very useful as an aid in producing a new type of centrifuge. I believe that it is going to allow us to increase the precision of the measurement of molecular weights, especially of the proteins.

The magnetic suspension used for supporting the mirror in these experiments may be slightly modified to make it into an excellent magnetic balance. We have succeeded in weighing weights of one milligram with a precision of about one billionth of a gram. This, of course, may find considerable use in industry.

Mr. Salzberg: Would it be possible to eliminate the use of the vacuum in rotating at relatively low speed?

Dr. Beams: Yes. However, the air friction goes up pretty rapidly with rotor speed.

Kenneth Shaftan: What material do you use?

Dr. Beams: We are using steel mostly. The rotor is made of the best steel we can get. We made some experiments on the bursting of different steels and we ran a long series on ordinary commercial ball bearings and on selected ball bearings. It turned out the ball bearings burst at the same peripheral speed if made of the same material. There were a great many flaws in the larger ball bearings. The probability of the rotor going up to full speed was roughly inversely proportional to the diameter of the rotor. I think that this result can be explained metallurgically.

Anon: What was the measurement between the solenoid field and the rotor itself?

Dr. Beams: Do you mean what distance?

Anon: Yes.

Dr. Beams: All the way from a few millimeters to 6 or 8. It is a variable thing, depending upon the field in the solenoid and its gradient at the rotor position.

Anon: What order of magnitude of power inversely is required to spin the bearing rotor?

Dr. Beams: Now, this is a relative matter, of course. I had one that was small, near $\frac{1}{16}$ in. in diameter, which started spinning slowly when the light from a Western Union electric arc was focused on its periphery. In other words, the light pressure was sufficient to spin it.

In this rotating mirror we had 1.6 amp to the coil and it accelerated at the rate of 1000 rpm. We try in most of our experiments to bring the rotor up as slowly as we can; by accelerating it faster, more heat is generated in the rotor. But under about one ampere in the coil the rotor increases in temperature less than 10°.

A. W. Carpenter: In bursting ball bearings could you tell me offhand within what angle it proved to be splaying or clipping?

Dr. Beams: Well, they sort of powdered and completely disintegrated. One also notices a little yellow light, like on a grinding wheel. You, of course, look through a right-angle mirror to see the yellow light.

E. A. Andres, Sr.: If I understood you correctly, you said you had 1.6 amp accelerated at 1000 rps...

Dr. Beams: No, 1000 rpm.

Mr. Andres: I would like to know how you made the measurement.

Dr. Beams: By photoelectron multiplier tube and a light-beam arrangement.

C. D. Miller: Dr. Beams, as you know at NACA we used a system similar to the one developed by you for supporting and driving a rotor used in a camera with which we took pictures at speeds up to 800,000 frame/sec. We used a rotor weighing about two-thirds of a pound,

about three inches long and about an inch in diameter.

I was interested in your remarks about the heating effect. We were not able to get an extremely good vacuum, as you have, because of certain mechanical limitations involved in our optical system. Because of the consequent high slip and resulting eddy currents, we ran into very serious heating of the rotor.

We eliminated the heating by resorting to what I call a self-synchronous motor. We cross-magnetized the rotor and drove it up to a few revolutions per second as an induction motor. Then, with two small coils alongside the lower end of the rotor, 90° apart, we picked up a four-phase voltage induced by the cross magnetization. We amplified this four-phase pickup, through both voltage and power amplifiers, and fed the output into the driving coils. We adjusted the positions of the pickup coils so that the rotating field was a little ahead of the cross magnetization of the rotor. The rotor then accelerated as a synchronous motor, and we avoided the heating altogether.

Dr. Beams: Yes. Yours was a very beautiful experiment. The method you used was certainly a good one. We have had to use a similar sort of scheme where we cannot have any temperature rise. The only reason we did not do it here is that the small mirrors do not get too hot. On the other hand, for larger rotors this is necessary.

Mr. Miller: I was wondering whether you found that the cross magnetization of the rotor would cause any undesirable effects in your experiments.

Dr. Beams: No, the cross magnetization seems not to upset anything else.

Anon: Mr. Miller, how much temperature rise did you encounter in the rotor when attempting to drive it up to full speed as an induction motor?

Mr. Miller: I did not measure the temperature rise except by touching the rotor with the hand. It was obviously excessive.

R. O. Painter: I wonder why the supporting field does not introduce eddy current flow. As I have it, there would be eddy current loss caused by this field since it fans out in the rotor.

Dr. Beams: Well, you see the magnetic field comes down uniformly across the rotor since the latter has a high permeability. Hence, there is no current flow.

Mr. Painter: Is it not generating eddy currents in the rotor periphery? You have a radial magnetic field.

Dr. Beams: You have a radial electrical field as it works out in practice. On the other hand, you have no closed circuit for the current unless the spin axis of the rotor makes a sizable angle with the direction of the magnetic field.

Mr. Painter: Between the center and the outside?

Dr. Beams: There is an electrical potential between the center and periphery of the rotor, but no current can flow.

Report of SMPTE Standards Committee

By FRANK E. CARLSON, Committee Chairman

The Standards Committee has continued to function with the type of organization and in accordance with the policies described in the preceding report.[1] This, the final report of the present Committee, includes not only a review of the work of the past two years, but also observations regarding the organization and policies of the Committee in the light of past experience.

Organization

The current practice of naming the Chairmen of the several Engineering Committees as members of the Standards Committee has proven quite satisfactory and it is recommended that this be continued. The objectives sought in appointing to this Committee the Chairmen of ASA sectional committees having interests closely related to the motion picture industry have not been realized, possibly because the activities of those committees during this period did not happen to bear on subjects of interest to motion pictures. In any event, since an important part of the related fields is represented in the Photographic Standards (Correlating) Committee, it seems desirable to reconsider the importance of such appointments. Participation by the Motion Picture Research Council and the few members-at-large has been commendable although, in the case of the MPRC, it was sometimes felt that the Committee would benefit if it were better informed of the Council's standards activities and interests.

Policies

The present practice of publication for trial and criticism, reviews, approvals, and reapprovals of proposed standards is different from the practices in many other and related fields. Unquestionably such thoroughness serves a useful purpose, but it must also be conceded that it adds to the Society's cost for processing standards and, in large measure, duplicates work which is the logical assignment of Sectional Committee PH22 of ASA. Since this Sectional Committee is sponsored by the SMPTE, and its membership is reviewed and approved by the Board of this Society, it is suggested that this present duplication of responsibility and effort be studied.

Coordination of Photographic Standards Work in ASA

Early in 1950 the Standards Council of ASA authorized the formation of a Photographic Standards (Correlating) Committee and, in accordance with ASA procedure, delegated to that Committee

Submitted as of December 27, 1951, by the Society's Standards Committee Chairman, Frank E. Carlson, General Electric Co., Nela Park, Cleveland 12, Ohio.

general administrative and supervisory responsibilities in this field. Prior to this time all proposed photographic standards were classified in the "miscellaneous" group and, like other miscellaneous standards, were identified by numbers which included the prefix letter Z. Formerly a standard approved by the old Sectional Committee Z22 had to be referred to the ASA Board of Examination which in turn had to refer it to the full Standards Council consisting of over 70 members. Since the formation of the Correlating Committee all proposed photographic standards (as well as revisions of old standards) are identified by the prefix PH. These proposals from one or another of the new Sectional Committee for photography go directly to the Correlating Committee and then to a six-man Board of Review for final approval. Thus, the formation of the Photographic Standards (Correlating) Committee has made possible substantial savings in both time and money.

It will be noted that, in subsequent sections of this report, standards or proposals are identified by Z22 numbers in some cases and PH22 numbers in others. This obviously reflects the change in organization just described. In the future all motion picture standards will be identified by the prefix PH22 as new standards are completed and old ones reviewed. Other photographic standards (formerly identified by Z38 numbers) will, in the future, be identified by the prefix PH1, PH2, PH3, or PH4, depending upon which of the four other new Sectional Committees for photography sponsored the proposal.

Standards Completed in 1950–1951

The following ten standards have been processed since the last report and have been adopted by ASA:

Z22.7-1950: Location and Size of Picture Aperture of 16mm Motion Picture Cameras[2]

Z22.8-1950: Location and Size of Picture Aperture of 16mm Motion Picture Projectors[2]

Z22.19-1950: Location and Size of Picture Aperture of 8mm Motion Picture Cameras[2]

Z22.20-1950: Location and Size of Picture Aperture of 8mm Motion Picture Projectors[2]

PH22.71-1950: Cutting and Perforating Dimensions for 32mm Sound Motion Picture Negative and Positive Raw Stock[3]

PH22.72-1950: Cutting and Perforating Dimensions for 32mm Silent Motion Picture Negative and Positive Raw Stock[3]

PH22.73-1951: Cutting and Perforating Dimensions for 32mm on 35mm Motion Picture Negative Raw Stock[4]

PH22.74-1951: Zero Point for Focusing Scales on 16mm and 8mm Motion Picture Cameras[4]

PH22.76-1951: Mounting Threads and Flange Focal Distances on 16mm and 8mm Motion Picture Cameras[4]

PH22.82-1951: Sound Transmission of Perforated Projection Screens[5]

Additionally, Z22.78-1950, Mounting Frames for Theater Projection Screens,[2] was adopted by ASA but not processed by the Standards Committee. This standard was developed by a subcommittee of ASA Sectional Committee Z22.

Similarly, the following three standards adopted by ASA were developed by the Joint SMPTE-MPRC Committee on Test Films:

Z22.79-1950: 16mm Sound Projector Test Film[2]

Z22.80-1950: Scanning-Beam Uniformity Test Film for 16mm Motion Picture Sound Reproducers (Laboratory Type)[6]

Z22.81-1950: Scanning-Beam Uniformity Test Film for 16mm Motion Picture Sound Reproducers (Service Type)[6]

The difficulties encountered in attempting to process a standard for 16mm and 8mm sprockets were described in the preceding report.[1] Accordingly, the Committee has published[7] an SMPTE Recommendation for 16mm and 8mm Sprocket Design for the guidance of sprocket designers. This material is in

a format such that it can be included in the Society's Standards Binder.

The Standards Committee has also completed its work on the following four proposals which have been submitted to ASA with the recommendation that they be adopted as American Standards:

PH22.11: 16mm Motion Picture Projection Reels[8]

PH22.83: Edge Numbering of 16mm Motion Picture Film[9]

PH22.24: Splices for 16mm Motion Picture Films for Projection[10]

PH22.77: Splices for 8mm Motion Picture Film[10]

Standards Currently in Process

PH22.15: Emulsion and Sound Record Positions in Camera for 16mm Sound Motion Picture Film[11]

PH22.16: Emulsion and Sound Record Positions in Projector for Direct Front Projection of 16mm Sound Motion Picture Film[11]

Both of the above are proposed revisions of Z22.15-1946 and Z22.17-1947, the most important detail of which is elimination of reference to the "guided edge." As sometimes happens in a case such as this, additional suggestions for improvement of the revision have been received with the result that a revised revision of the proposal is scheduled for republication shortly.

PH22.86: Dimensions for Magnetic Sound Tracks on 35mm and 17½mm Motion Picture Film[12]

PH22.87: Dimensions for Magnetic Sound Track on 16mm Motion Picture Film[12]

PH22.88: Dimensions for Magnetic Sound Track on 8mm Motion Picture Film[12]

These badly needed proposals are the work of the Subcommittee on Magnetic Recording of the Sound Committee and the comments which have resulted from preliminary publication are now being reviewed by that Committee.

Z22.75: A and B Windings of 16mm Raw Stock Film With Perforations Along One Edge[13]

This proposal, originally an SMPE Recommendation adopted in 1941, has given the 16mm and 8mm Motion Pictures Committee a great deal of trouble. It was first published as a proposed standard in September, 1949; the present revision of the proposal, which appeared in January, 1951, has brought forth suggestions for further changes, with the result that it has been again referred to the sponsoring Committee.

PH22.84: Dimensions for Projection Lamps, Medium Prefocus Ring Double-Contact Base-Up Type[3]

PH22.85: Dimensions for Projection Lamps, Medium Prefocus Base-Down Type[3]

These two proposals, developed by the 16mm and 8mm Motion Pictures Committee, seem to be about ready for final action by the Standards Committee on the question of submittal to ASA.

PH22.1: Cutting and Perforating Dimensions for 35mm Motion Picture Film — Alternate Standards for Either Positive or Negative Raw Stock[14]

The history of this proposal since 1932 is briefly set forth in the *Journal* and is an example of the complexity of the problems that frequently confront the Film Dimensions Committee.

Other proposals on the Agenda of the Standards Committee which have not yet reached the stage of publication for trial and comment include the following:

Revision of Z22.41-1946, Sound Records and Scanning Area of 16mm Sound Motion Picture Prints, again with particular reference to the question of "guided edge." The Sound Committee is considering this question to determine what can be done to establish consistency with related standards without degradation of 16mm sound quality.

Aperture Calibration of Motion Picture Lenses, a proposal developed by the Optics Committee, has encountered strong criticism in the initial ballot of the Standards Committee on the question of preliminary publication.

Enlargement Ratio for 16mm to 35mm Optical Printing is a new proposal developed by the Laboratory Practice Committee and will probably appear in an early issue of the *Journal*. [See the Jan. 1952 *Journal*.]

16mm Motion Picture Projector for Use With Television Film Chains Operating on Full-Storage Basis. This is a proposal developed by the joint RTMA-SMPTE Committee on Television Film Equipment and is encountering opposition on the Standards Committee initial ballot.

Under ASA procedure, existing standards are re-examined periodically for the purpose of determining whether the Standard should be reaffirmed in its present form, be revised in the light of new developments or changing practices, or rescinded because it is no longer of value. The responsibility for such review is delegated to the several Engineering Committees and two of them have recently submitted recommendations to the Standards Committee for further action. These include:

Nomenclature for Electrical Filters, Z22.33-1941. The Sound Committee has recommended that this Standard be discontinued because it finds that the method described for designating electrical filters has had very little use and has no further value.

Emulsion Position in Projector for Direct Front Projection of 16mm Silent Motion Picture Film, Z22.10-1947.

Emulsion Position in Projector for Direct Front Projection of 8mm Silent Motion Picture Film, Z22.22-1947. Here too, the Committee on 16mm and 8mm Motion Pictures recommends that these standards be discontinued because films for projection are produced by such a variety of processes that the Standards are no longer of value.

Finally, the Engineering Vice-President has asked the Standards Committee to assist in another effort to develop a glossary. As a first step in this program, work done in the early 1940's on this subject is being subdivided by the Society's Staff Engineer into parts corresponding to the scopes of the several Engineering Committees. Thus, work already done need not be duplicated by those Committees. It is expected that this initial work will be completed in time for the several Committees to begin work early in their new terms.

References

1. "Report of the Standards Committee," *Jour. SMPTE, 54:* 102–105, Jan. 1950.
2. "New American Standards," *Jour. SMPTE, 54:* 494–507, Apr. 1950.
3. "Standards," *Jour. SMPTE, 56:* 235–246, Feb. 1951.
4. "Three New Standards," *Jour. SMPTE, 56:* 684–689, June 1951.
5. "New American Standards," *Jour. SMPTE, 57:* 170–171, Aug. 1951.
6. "New American Standards," *Jour. SMPTE, 55:* 117–119, July 1950.
7. "Recommendations for 16mm and 8mm Sprocket Design," *Jour. SMPTE, 54:* 219–228, Feb. 1950.
8. "Proposed American Standard, 16mm Projection Reels," *Jour. SMPTE, 54:* 229–231, Feb. 1950.
9. "Edge Numbering of 16mm Motion Picture Film," *Jour. SMPTE, 56:* 115, Jan. 1951.
10. "Splices for 16mm and 8mm Film," *Jour. SMPTE, 56:* 354–361, Mar. 1951.
11. "Revision of PH22.15 and PH22.16," *Jour. SMPTE, 56:* 559–561, May 1951.
12. "Proposed American Standards," *Jour. SMPTE, 57:* 71–74, July 1951.
13. "A and B Windings of 16mm Raw Stock Film With Perforations Along One Edge," *Jour. SMPTE, 56:* 112–113, Jan. 1951.
14. "Proposed American Standard," *Jour. SMPTE, 57:* 275–278, Sept. 1951.

71st Semiannual Convention

The Spring Convention at The Drake in Chicago on April 21–25 is well planned already by many good hands, some of whom were noted in the report in the January *Journal.*

BUT **now is the time for all good authors** to hasten information about their papers for the Convention to the proper authority.

If you don't have an Authors' Form or can't readily get one from one of the Papers Committeemen listed in the January *Journal*, ask the Society's headquarters office for one.

AND in the meantime, **not merely in posthaste but by wire,** advise the 71st Convention Program Cochairman on the spot in Chicago:

Telegraph: George W. Colburn, 164 N. Wacker Drive, Chicago 6, Ill.

The sooner you send word, the easier will be the work of arranging the program in the form of sessions, which is the job of the Program Cochairmen, R. T. Van Niman and George Colburn.

Convention Vice-President Bill Kunzmann gave a detailed report of plans for the Convention to the Society's Board of Governors in January, and from that report and later information from Bill, as well as from C. E. Heppberger, we have the following roster of the folks who will put on the Chicago Convention:

Program Cochairmen — R. T. Van Niman and George W. Colburn

Local Arrangements — C. E. Heppberger

High-Speed Photography — Richard O. Painter

Hotel Reservations and Transportation — W. C. De Vry

Luncheon and Banquet — George W. Colburn

Membership and Subscriptions — Ray Gallo and Samuel R. Todd

Motion Pictures Program — L. E. Weber, assisted by R. J. Sherry

Projection, 16mm — E. W. D'Arcy

Projection, 35mm — I. F. Jacobsen, assisted by Officers and Members of Local 110, IATSE

Public Address and Recording — Robert P. Burns

Publicity — Harold Desfor and Leonard Bidwell

Registration and Information — James L. Wassell, assisted by E. W. D'Arcy, J. E. Dickert, Steve Hunter, C. L. Lootens, K. M. Mason, John S. Powers and Reid H. Ray

Television — William C. Eddy

Ladies' Registration — Mrs. George W. Colburn and Mrs. C. E. Heppberger, Cohostesses, assisted by the wives of the Central Section's Officers and Managers

Early in March, all members will receive the Advance Notice of the Convention, which will contain a condensed schedule of the Convention sessions and will have attached the usual tear-off postal for making hotel reservations. Bill Kunzmann has received from John R. Bogardus, Front Office Manager, The Drake, Lake Shore Drive & Upper Michigan Ave., Chicago 11, Ill., the following rates:

Single room, per day	$5.50; 6.00; 6.50; 7.00; 7.50.
Double room with twin beds, per day	$9.00; 10.00; 11.00; 12.00; 14.00; 15.00.
Suite parlor and one bedroom, per day	$16.00; 18.00; 19.00; 26.00; 33.00; & up.

Board of Governors Meeting

The Society's Board of Governors held its first 1952 meeting on January 24, in New York City. This is the meeting at which the members of the Board examine the previous year's operations, comparing carefully the report of actual performance for last year against the budget that was set up in January 1951.

EXECUTIVE COMMITTEE

Most significant administrative development of 1951 was the appointment by President Peter Mole of an Executive Committee which will assume some of the operational advisory functions formerly exercised directly by the Board of Governors. Growth of the Society's business and the importance of a number of its activities in the almost daily evolution of television and the current technical growth of motion pictures call for closer supervision of the headquarters operations than the Board of Governors could provide with its regular quarterly meetings. As a consequence, the Executive Committee will meet monthly, or more often if necessary, consult with the staff, examine the precise details of operation on a month-to-month basis and will submit recommendations for consideration by the Board of Governors when that body meets every third month. Under this arrangement, matters of general policy and questions of membership or industrial services provided by the Society can receive proper Board attention while details of execution will in general be left to the discretion of the executive body.

ENGINEERING

Test film operations were placed on a somewhat more secure footing when Fred Whitney joined the headquarters staff during the early part of 1951 and took charge of test film quality control. Precision required by American Standards or by specifications developed by Society committees for motion picture test films demands careful supervision of production. In addition, development of certain new test films through the coming year will necessitate not only agreement on the manner in which the films are produced but also agreement on standard methods of testing. It will be Mr. Whitney's responsibility to spell out these test methods in detail and submit them for consideration by the Test Film Quality Control Committee.

PUBLISHING

The report of the Editorial Vice-President pointed out *Journal* changes made during 1951 which have been considered a marked improvement. The new style provides more words per page and the combination of type face, line length and line spacing contributes to easier reading and yields more printed words per publication dollar than was possible in the older format. With the new format now well in hand, the major objective for 1952 is the adoption of more realistic publication dates. The first three issues for 1952 will probably be somewhat thinner than usual and it is expected that the May issue will be out by the 15th of that month.

The actual cost of producing the twelve copies of the *Journal* which each member receives annually is a figure that has been quite difficult to arrive at, considering the recent major changes in accounting, the manner of operating Society Headquarters plus the format changes of the past year. Since things are now settling down, the Board asks that Headquarters prepare such a cost analysis with a view toward determining whether or not each member's dues pays his share of the cost of operating the Society. Figures that result from pro rata allocation of costs depend, of course, on membership. Unit costs go down as the total number of members goes up. That brought up the question of membership solicitation activities for last year and also for 1951.

MEMBERSHIP

A new committee, under the Chairmanship of Ray Gallo of Quigley Publications and with Beatrice Conlon of the Society Headquarters as full-time Secretary, is attempting something new in the way of membership work. Between 65 and 100 company or city member-delegates are being selected and each will be armed

with advance information about conventions, Society committees, Section meetings and membership and publications ammunition. Each of these member-delegates will be the focal point for Society information in his own community. It is hoped that many questions about the SMPTE, its engineering activities and membership requirements can be answered on the spot, to the benefit not only of the inquirer but of the Society as well.

SECTIONS

Reports of the three Section Chairmen were read into the record and it was noted that extra effort at organizing Section meeting programs was almost invariably rewarded by an increase of attendance, entirely justifying the added costs of rented chairs or screening-room facilities. Popular reaction to the repeating of Convention papers at Section meetings brought an official request for the recording on magnetic tape of certain papers for re-presentation with accompanying slides. It was suggested that a small library of such papers be assembled and made available in appropriate batches for regional meetings or student chapter sessions. There was also a formal recommendation that the Student Chapters in Hollywood and in New York should function under the supervision of the local Section Chairmen and Boards of Managers. This would probably result in the more efficient use of funds and perhaps encourage Chapter participation in local Section meetings.

CONVENTIONS

The report of the Convention Vice-President concluded, with some enthusiasm, that the two Conventions held in 1951 had drawn better attendance than any in previous years. As a consequence, plans for the Spring and Fall Conventions in 1952 are being adjusted to provide facilities for the larger registration. The following dates were reported to and approved by the Board of Governors:

71st Convention: The Drake, Chicago, Ill., April 21–25, 1952
72nd Convention: Hotel Statler, Washington, D.C., October 6–10, 1952
73rd Convention: Hotel Statler, Los Angeles, Calif., April 26–30, 1953
74th Convention: Hotel Statler, New York, N.Y., October 4–9, 1953

Engineering Activities

New Chairmen Engineering Committees are appointed in accordance with Section V of the Society Bylaws, which states that the term of appointment expires every two years, along with the term of the appointing officer (the Engineering Vice-President) and further that Committee Chairmen are eligible for one reappointment, or for a total service of 4 years. (There is no limit on the reappointment of members, except that imposed by their degree of interest in the work of the committee.)

The four-year limitation now requires that Fred Bowditch as Engineering Vice-President appoint new chairmen to six committees, four of whom are:

Standards, Henry Hood, Eastman Kodak
16 & 8, Malcolm Townsley, Bell & Howell
Sound, John Hilliard, Altec Lansing
Motion Picture Studio Lighting Process Photography, John W. Boyle

The two committees still without new Chairmen are Color and High-Speed Photography. It is expected that they can be announced in the next *Journal*.

ISO The Technical Committee on Cinematography of the International Organization for Standardization (ISO TC/36) was canvassed as to their interest in a meeting in New York on June 9 and 10, 1952, as mentioned in the previous issue. Affirmative replies have since been received from Belgium, Canada, France, Germany, Italy and the United Kingdom. Based on this response, the Chairman of the ASA Sectional Committee PH 22, Dr. D. R. White, and the SMPTE Engineering Vice-President, Fred Bowditch, recommended to the ASA that the meeting be scheduled. A proposed Agenda is now being formulated, on the recommendations of the SMPTE Engineering Committees, secured in anticipation of such a meeting and including items submitted by several of the member nations. ISO procedure requires the Agenda to be circulated to all members four months prior to the meeting, in this instance by February 9, 1952. As Secretariat the United States will chair the meeting.—*Henry Kogel*, Staff Engineer.

Book Reviews

Fundamental Mechanisms of Photographic Sensitivity

(Proceedings of a Symposium held at the University of Bristol in March 1950.) Edited by J. W. Mitchell. Published (1951) by Butterworths Scientific Publications, London. Distributed in U.S.A. by Academic Press, 125 E. 23 St., New York 10. i-viii + 347 pp. + 270 illus. 7 × 9¾ in. Price $9.50.

This represents an excellent and up-to-date review of data and theories on the fundamental mechanisms of photographic sensitivity. Original papers as presented at an International Conference in Bristol, England, in March 1950, have been assembled in book form by the editor.

By arranging the papers in groups, such as "Photographic Sensitivity" and "Latent Image Formation," the editor has made it convenient for the reader to follow the latest trends and developments in these concepts. Professor N. F. Mott, in an introduction to the book, outlines the latent image theory as proposed by him and Gurney in 1938 and gives its present status, pointing out the problems which still need explanation. This introduction will be helpful to those who are not too familiar with the subject.

The book contains contributions and first publications of papers from a large number of European, British and American scientists. It is interesting to note from these papers that their various observations and theories about latent image formation, photographic sensitivity and optical and chemical sensitization begin to dovetail with the basic concept of Gurney and Mott and the evolution of this theory by concepts proposed by Pohl, Stasiw and Teltow, West, Mitchell and others.

The book also contains a series of articles under the general headings: "Physical Properties of Silver Halide," "Production and Properties of Silver Halide Grains in Photographic Emulsions" and "Nuclear Track Emulsion." A summary prepared by the editor after the conference gives a critical review of the status of the theory of the physical properties of the silver halides and the theory of photographic sensitivity as it appeared to him.

The book will be of interest primarily to those working in the field of photographic research and development; however, it should also appeal to those working on practical applications of photography and interested in knowing what makes photography work. The book is well printed and illustrated.—*Herman H. Duerr*, Ansco, Binghamton, N.Y.

Einführung in die wissenschaftliche Kinematographie (Introduction to Scientific Motion Picture Photography)

By Dr. Werner Faasch. *In German.* Published (1951) by Verlag von Wilhelm Knapp/Halle (Saale), Germany. 76 pp. + 63 illus. 5¾ × 8 in. Available in U.S.A. from Stechert-Hafner, Inc., 31 E. 10 St., New York 3. Price $1.30.

At this time, when photography is being recognized more and more as an indispensable tool for scientific and technical investigation, the appearance of any book which surveys some part of the field should not be ignored. This book is intended merely as an introductory survey to the applications of motion picture photography as a means of scientific study.

The opening chapter is concerned with time-lapse and high-speed motion picture studies, and in particular with German apparatus for use in these fields.

Among the special applications of motion picture photography dealt with in succeeding chapters are motion photomicrography, x-ray and electron microscope motion photography, endoscopic studies and photography of operations, astronomical and photoelastic studies, Schlieren photography and a number of other applications. The final chapter treats the important subject of evaluation of the photograph.

The book would have its greatest appeal to the general reader. It is confined to known practices, and is devoted almost entirely to German equipment. It is well illustrated.—*Walter Clark*, Kodak Research Laboratories, Rochester 4, N.Y.

New Members

The following members have been added to the Society's rolls since those last published. The designations of grades are the same as those used in the 1950 MEMBERSHIP DIRECTORY.

Honorary (**H**) Fellow (**F**) Active (**M**) Associate (**A**) Student (**S**)

Angwin, Bruce S., Regional Sales Manager, Equipment Tubes, General Electric Co., Electronics Div. **Mail:** 238 North Frederic St., Burbank, Calif. (**A**)

Avil, Gordon, Free-lance Motion Picture Cameraman. **Mail:** 13809 Weddington St., Van Nuys, Calif. (**A**)

Baldridge, Claude C., Motion Picture Supervisor, U.S. Air Force, Edwards Air Force Base, Edwards, Calif. (**A**)

Bisno, Lou, Production Assistant, Snader Telescriptions Corp. **Mail:** 530 North Frederic St., Burbank, Calif. (**M**)

Bridge, Harry P., University of Maine. **Mail:** 109 Commercial St., Boothbay Harbor, Me. (**S**)

Bryant, Harry L., Recording Engineer, Radio Recorders. **Mail:** 4350 Chevy Chase Dr., La Canada, Calif. (**M**)

Buxbaum, Morton L., New Inst. for Film and Television. **Mail:** 357 Milford St., Brooklyn 8, N.Y. (**S**)

Cain, Donald G., University of Minnesota. **Mail:** 5125 South Washburn, Minneapolis 10, Minn. (**S**)

Chaikofsky, Samuel, New Inst. of Film and Television. **Mail:** 2504 Bronx Park East, New York 67, N.Y. (**S**)

Crevenna, Alfredo B., Writer and Motion Picture Director. Ultramar Films. **Mail:** Parque Melchor Ocampo 28, Dep. 5, Mexico, D.F., Mexico. (**A**)

Curtis, Harold K., Foreman, Release Dept., Paramount Pictures Laboratory. **Mail:** 9021 Dicks St., Los Angeles 46, Calif. (**A**)

Dixon, Herbert W., Television Motion Picture Production, John Sutherland Productions, Inc. **Mail:** 11280 Brookhaven Ave., Los Angeles, Calif. (**M**)

Downey, C. E., Television Engineer, KGO-TV. **Mail:** 119 Villanova Dr., Oakland 11, Calif. (**A**)

Eckes, John D., Jr., Supervisor, Camera Dept., United Productions of America. **Mail:** 362 South Myers St., Burbank, Calif. (**A**)

Elliott, Richard S., Senior Photographer, Motion Picture Div., University of Southern California at Los Angeles. **Mail:** 550¾ South Barrington, Los Angeles 49, Calif. (**A**)

Fallis, Marne F., Projectionist, United Productions of America. **Mail:** 156 South Pacific Ave., Glendale 4, Calif. (**A**)

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Meetings

The Central Section of the SMPTE has scheduled two papers for its meeting at the Bell & Howell Co., 7100 McCormick Blvd., Chicago, on March 27. Bruno G. Staffen, development engineer of the Jensen Manufacturing Co., will describe a new low-cost theater speaker system, and there will be a description of the new Bell & Howell magnetic and optical 16mm sound projector by J. B. Weber, H. H. Brauer, F. J. Schussler and M. G. Townsley. C. E. Heppberger is Central Section Chairman, and John S. Powers is Program Chairman.

71st Semiannual Convention of the SMPTE, April 21–25, The Drake, Chicago

Other Societies

I.R.E. National Convention, Radio Engineering Show, Mar. 3–6, Hotel Waldorf-Astoria and Grand Central Palace, New York

National Electrical Manufacturers Association, Mar. 10–13, Edgewater Beach Hotel, Chicago, Ill.

American Physical Society, Mar. 20–22, Columbus, Ohio

Optical Society of America, Mar. 20–22, Hotel Statler, New York

American Physical Society, May 1–3, Washington, D.C.

Acoustical Society of America, May 8–10, New York

American Institute of Electrical Engineers, Summer General Meeting, June 23–27, Hotel Nicollet, Minneapolis, Minn.

American Physical Society, June 30–July 3, Denver, Colo.

Photographic Society of America, Annual Convention, Aug. 12–16, Hotel New Yorker, New York

American Institute of Electrical Engineers, Pacific General Meeting, Aug. 19–22, Hotel Westward Ho, Phoenix, Ariz.

Illuminating Engineering Society, National Technical Conference, Aug. 27–30, Washington, D.C.

SMPTE Officers and Committees: The roster of Society Officers and the Committee Chairmen and Members were published in the April 1951 *Journal*.

New Products

Further information about these items can be obtained direct from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of these items does not constitute endorsement of the products.

A playback recorder that puts 60 min of speech or music on a vinylite disc 4¾ in. in diameter, operating at 16 rpm and at a pitch of 448 lines/in. is the "Wagner-16" MicroDisc Recorder, Model P16-450. The portable carrying case, weighing 28 lb complete, contains the complete mechanism and recording head, amplifier and power supply, playback pickup and loudspeaker for recording and playing back.

Although it is recommended that the prime application for MicroDiscs is in reference, closed circuit and conference work, the manufacturer claims that fidelity of reproduction is also excellent for musical material. The disc drive uses no turntable, which, it is said, eliminates all flutter and wow, enabling extended bass response. The design of the feed screw affords accuracy of pitch, it is said, as great as that found in the most professional recorders. The "Wagner-16" also features "spiralling," and a "magic-eye" volume-level indicator is an integral part of the equipment. A recording time reference scale operates automatically. Two input receptacles, switch selected, are provided, one for the microphone and the other for "bridging." The equipment operates from 115 volts, 60-cycle a-c, with 50-cycle optional.

MicroDisc blanks are $2.50 for a package of 12. The complete MicroDisc recorder includes all styli (sapphire), microphone, PM loudspeaker, extra input plugs and instruction manual, at a cost of $295 from the Audio & Video Products Corp., 730 Fifth Ave., New York 19, N.Y.

Film Research Associates, located at 150 E. 52 St., New York 22, N.Y. publishes and distributes seven guides to available training aids. Listed are the sources of functional films for meetings, conferences, classes or study groups, with alphabetically arranged descriptions of type, running time and use. Procedures are recommended for effectively using audio-visual methods. The guides are priced separately at $1.00 to $2.00 and the complete set of seven publications is $9.00.

American Standards form the technical foundation for motion pictures around the world. All current standards were listed by subject and by number in the *Journal* Index 1946–1950. Reprint copies of this list, which includes all previous *Journal* references to each standard, are available from Society Headquarters without charge.

Complete sets of all sixty current standards in a heavy three-post binder with the index are $13.50, plus 3% sales tax for purchases within New York City, and are available from Society Headquarters. Single copies of any particular standard must be ordered from the American Standards Association, 70 East 45th St., New York 17, N.Y.

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